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THESIS

A SIMULATION TO DETERMINE THE EFFECT THAT THE ARMY BASIC OFFICER LEADERSHIP COURSE WILL HAVE ON ACCESSION TRAINING

by

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June 2002

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The United States Army is currently considering a significant change in the way they train newly commissioned officers. The Army's Training and Doctrine Command (TRADOC) plans to add a course to accession training called the Basic Officer Leadership Course (BOLC), which would teach officers of all Army Competitive Category (ACC) branches core leadership and common skills requirements at three Army installations in the United States. This thesis develops a simulation that explores the length of time newly commissioned officers spend training once TRADOC implements BOLC and establishes training policies for the new course. The model is implemented in the Java programming language, with Simkit as the simulation package. The simulation output is a list of 225,000 simulated officers with their training time recorded, which I aggregate into mean and variance measurements for each design point. Upon this aggregated data I execute a regression analysis, which feeds into a loss function that penalizes excess time spent in accession training. Minimizing the loss function returns optimal policy settings for BOLC's implementation. This analysis shows that the most significant policies in the accession training system are the maximum and minimum class size for a BOLC class and the ratio of ROTC officers who receive immediate active duty status upon commissioning. My analysis also shows that placing BOLC into the simulated accession training system caused an increase of approximately 23 days in training time.

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ABSTRACT

The United States Army is currently considering a significant change in the way they train newly commissioned officers. The Army’s Training and Doctrine Command (TRADOC) plans to add a course to accession training called the Basic Officer Leadership Course (BOLC), which would teach officers of all Army Competitive Category (ACC) branches core leadership and common skills requirements at three Army installations in the United States. This thesis develops a simulation that explores the length of time newly commissioned officers spend training once TRADOC implements BOLC and establishes training policies for the new course. The model is implemented in the Java programming language, with Simkit as the simulation package. The simulation output is a list of 225,000 simulated officers with their training time recorded, which I aggregate into mean and variance measurements for each design point. Upon this aggregated data I execute a regression analysis, which feeds into a loss function that penalizes excess time spent in accession training. Minimizing the loss function returns optimal policy settings for BOLC’s implementation. This analysis shows that the most significant policies in the accession training system are the maximum and minimum class size for a BOLC class and the ratio of ROTC officers who receive immediate active duty status upon commissioning. My analysis also shows that placing BOLC into the simulated accession training system caused an increase of approximately 23 days in training time.

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TABLE OF CONTENTS

I. INTRODUCTION 1
A. CURRENT ACCESSION TRAINING 1
B. PROPOSED CHANGES TO ACCESSION TRAINING 2
C. THE EFFECT OF THE BASIC OFFICER LEADERSHIP COURSE ON ACCESSION TRAINING 6
1. The Importance of the Transient, Holdee and Student Account 7
2. Modeling Approach 9
D. RELATED RESEARCH 10

II. MODEL 15
A. PROBLEM STATEMENT 15
B. EVENT GRAPHS 15
C. ACCESSION TRAINING EVENT GRAPHS AND DISCUSSION ... 18
1. Accession 20
2. BOLC 27
3. OBC 33
4. Operational Assignment 36
D. SIMULATION VALIDATION 36
E. ASSUMPTIONS 39

III. EXPERIMENTAL DESIGN 41
A. EXPERIMENT FACTORS AND LEVELS 41
1. BOLC Branch Ratio Restriction 41
2. Minimum OBC Course Size Requirement 42
3. BOLC Minimum Course Size or Difference Between Maximum and Minimum BOLC Class Size . 42
4. BOLC Maximum Class Size 43
5. Immediate Active Duty Ratio 44
B. REGRESSION EQUATION 46
C. GRIDDED FACTORIAL EXPERIMENT DESIGNS 47
D. ROBUST EXPERIMENT DESIGN 49
E. USE OF RANDOM NUMBERS 53

IV. EXPERIMENT RESULTS AND RESPONSE SURFACE ANALYSIS 55
A. INITIAL REGRESSION RESULTS 55
1. Grand Mean Regression Analysis 55
2. Variance Regression Analysis 62
B. RESPONSE SURFACE ANALYSIS 69
1. BOLC Branch Ratio 70
2. Min OBC Course Size Requirement 71
3. Max BOLC Class Size, Min BOLC Class Size, and Immediate Active Duty Ratio 71

C. RUNNING BASELINE SIMULATION AT OPTIMAL POLICY SETTINGS 77

V. CONCLUSIONS AND RECOMMENDATIONS 81
A. CONCLUSIONS 81
B. RECOMMENDATIONS 81
C. FURTHER RESEARCH 82
1. Improving the Simulation 82
2. Cost Analysis 83
3. Changes to Current Analysis 84

APPENDIX A. ACCESSION INPUT DATA 91
WEST POINT INPUT DATA 91
ROTC INPUT DATA 93
OCS INPUT DATA 95

APPENDIX B. BOLC INPUT DATA 97

APPENDIX C. OBC INPUT DATA 99

APPENDIX D. EXPERIMENT DESIGN POINTS 105

APPENDIX E. MEAN ACCESSION TIME REGRESSION RESULTS 107

APPENDIX F. VARIANCE REGRESSION RESULTS 109

APPENDIX G. FORMULATION OF LOSS FUNCTION MINIMIZATION 111

INITIAL DISTRIBUTION LIST 113

LIST OF FIGURES

Figure 1. Accession Training System with BOLC Implemented ... 5
Figure 2. A General Event Graph for Explanation 17
Figure 3. Simulation Breakdown 18
Figure 4. Accession Event Graph 21
Figure 5. BOLC Event Graph 27
Figure 6. OBC Event Graph 33
Figure 7. Scatterplots of Variables and Mean Accession Training Time 56
Figure 8. Grand Mean Scatterplots Minus Outliers 57
Figure 9. Predicted vs. Residuals in Grand Mean Regression . 61
Figure 10. Scatterplots of Variables and Variance 63
Figure 11. Predicted Variance vs. Residuals Plot with Max BOLC Class Size as the Predictor Variable 64
Figure 12. Predicted vs. Residuals in Variance Regression 66
Figure 13. Predicted vs. Residuals in Transformed Variance 68
Figure 14. Graph of Loss Function 73
Figure 15. Loss Function Values at Each Design Point ... 76

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LIST OF TABLES

Table 1. Validation Model Results 38
Table 2. Summary of Controllable Factors and Their Levels . 45
Table 3. Results of Simulation at Optimal Policy Settings . 74
Table 4. Design Points with Low Loss Function Values 77
Table 5. Baseline Model Run at Optimal BOLC Policy Settings 78
Table 6. West Point Branch Graduation Rates 91
Table 7. West Point Graduation Dates and Class Size 92
Table 8. Ratios of Graduation Delay for West Point Graduating Classes 92
Table 9. ROTC Branch Graduation Rates 93
Table 10. Ratio of ROTC Graduates Categorized Immediate Active Duty 93
Table 11. ROTC Graduation Dates and Graduating Class Size .. 94
Table 12. ROTC Graduation Delay Data (Days) 94
Table 13. OCS Branch Graduation Rates 95
Table 14. OCS Graduation Delay Data (Days) 95
Table 15. OCS Graduation Dates and Graduating Class Size ... 96
Table 16. General BOLC Input Data 97
Table 17. BOLC Attrition and Recycle Rates 97
Table 18. BOLC Scheduled Start Dates by Installation 98
Table 19. OBC Travel Data 99
Table 20. OBC Attrition and Recycle Rates by Branch 100
Table 21. OBC Course Length, Minimum and Maximum Sizes 101
Table 22. Air Defense OBC Schedule 101
Table 23. Adjutant General OBC Schedule 101
Table 24. Armor OBC Schedule 102
Table 25. Aviation OBC Schedule 102
Table 26. Chemical OBC Schedule 102
Table 27. Engineer OBC Schedule 102
Table 28. Field Artillery OBC Schedule 102
Table 29. Finance OBC Schedule 103
Table 30. Infantry OBC Schedule 103
Table 31. Military Intelligence OBC Schedule 103
Table 32. Military Police OBC Schedule 103
Table 33. Ordnance OBC Schedule 103
Table 34. Quartermaster OBC Schedule 104
Table 35. Signal Corps OBC Schedule 104
Table 36. Transportation OBC Schedule 104

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LIST OF ACRONYMS AND ABBREVIATIONS

2LT	Second Lieutenant
ACC	Army Competitive Category
Avg	Average
BOLC	Basic Officer Leadership Course
CDF	Cumulative Distribution Function
Est	Estimated
Ft.	Fort
GMRE	Grand Mean Regression Equation
IA	Immediate Active Duty
IOBC	Infantry Officer Basic Course
Loc	Location
Max	Maximum
MFSAD	Military Forecasting and Strength Analysis Division
Min	Minimum
OBC	Officer Basic Course
OCS	Officer Candidate School
ODP	Officer Distribution Plan
OP STR	Operational Strength
PCS	Permanent Change of Station
PERSCOM	Army Personnel Command
Req	Requirement
ROTC	Reserve Officer Training Corps
THS	Transient, Holdee and Student
TTT	Total Training Time
Var(TTT)	Variance of Total Training Time
TRADOC	Training and Doctrine Command
vs.	Versus
VRE	Variance Regression Equation

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EXECUTIVE SUMMARY

The Army is considering implementing a significant change to its standing accession training. Training and Doctrine Command (TRADOC), responsible for all formal training schools within in the Army, plans to introduce a new course to the accession training scheme called the Basic Officer Leadership Course (BOLC). This new course will train newly commissioned second lieutenants (2LT) in the common core points of instruction (POI); these POIs include such tasks as land navigation and basic rifle marksmanship.

With BOLC's implementation, the traditional officer basic courses (OBC) for each of the Army Competitive Category (ACC) branches will reduce the length of their respective courses. Since initial plans for BOLC show a course length of 35 training days, TRADOC requires the OBCs to reduce their course length by a similar amount.

Military Forecasting and Strength Analysis Division (MFSAD) of the Deputy Chief of Staff, Army G-1 has concerns with respect to the introduction in BOLC. As the primary analysts responsible for the management of the Transient, Holdee and Student (THS) Account, they want to know the impact that this change to the accession training system will have on the time it requires to train 2LTs.

The THS account is a database that contains all soldiers in the Army who are not assigned to an operational unit. That is to say, they are not in "foxholes" performing Army missions. The greater the size of the THS account, the less capable the Army is of meeting mission requirements. Officers participating in accession training are an explicit piece of the THS account. Any changes to the accession training system will have an impact on the size of the THS account.

However, TRADOC has not officially published many of the policies for BOLC's implementation. Some of these policies are the maximum/minimum BOLC class size and whether they will impose any constraints on a BOLC class consistency.

To determine the effect that BOLC and TRADOC's policies for its implementation will have on the THS account, this thesis develops a simulation written in Java using a simulation package called Simkit. The simulation replicates the accession training environment after BOLC's implementation by breaking the accession training system into four modules, Accession, BOLC, OBC and Operational Assignment.

This thesis includes an experiment design that governs the use of the simulation in its exploration of BOLC's effects on the THS account. The specific factors included in the experiment and adjusted as parameters in the simulation are the maximum BOLC course size, the difference between the maximum and minimum BOLC course size, the BOLC Army branch ratio policy for class consistency, whether or not there is a minimum course size requirement for OBC, and the immediate active duty ratio for 2LTs from the Reserve Officer Training Corps (ROTC).

After running the simulation according to the experiment design and building a response surface model on the output, the TRADOC policies that have the most impact on the THS account are the maximum and minimum BOLC course sizes. The immediate active duty ratio for ROTC officers is also extremely important to the size of the THS account.

I used the regression model in an optimization where the policies in them were set to levels to minimize THS account size due to accession training time. With these optimal policies, I ran a simulation that emulates the current accession training system, that is without BOLC. The simulation with BOLC which I ran at the optimal policy settings returned an average accession training time per officer approximately 23 days higher than the simulation without BOLC.

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I. INTRODUCTION

A. CURRENT ACCESSION TRAINING

The Army commissions Army Competitive Category (ACC) second lieutenants (2LT) primarily from three main sources: The United States Military Academy at West Point, New York, colleges that have a Reserve Officer Training Corps (ROTC), and the Officer Candidate School (OCS) at Fort Benning, Georgia. Army Competitive Category officers are all those in the Army excluding Chaplains, Judge Advocate General Corps, Nurse Corps, Medical Service Corps, and Veterinarian Corps officers. Upon graduation from one of these three programs, officers begin their accession training, which for the purpose of this thesis I loosely define as all training programs and schools that newly commissioned officers attend and complete prior to arrival at their first operational assignment.

Once commissioned, the majority of the second lieutenants take an authorized delay before reporting for their first training assignment. After their leave, officers arrive at their first training site. This might be at one of the Army’s military training courses, such as Airborne or Air Assault School. The second lieutenant may also go directly to their Officer Basic Course (OBC) without attending a military training course.

The Officer Basic Course provides officers their first glimpse into the aspects of their specialty in the Army. The course instructs second lieutenants on things such as customs and courtesies in the service, land navigation, rifle marksmanship and the technical points of instruction for their specialty. There is an OBC for each branch of the Army, and twelve different installations host 15 ACC Officer Basic Courses. Officer Basic Courses average about 17 or 18 weeks in length, with Aviation OBC lasting the longest at 22 weeks, and Finance the shortest at eleven weeks.

After completing OBC, officers can then attend military training if they require it, or they can attend other specialty schools. For example, Adjutant General officers are responsible for the Army's postal system. Second Lieutenants assigned to a postal unit for their first assignment would spend two to three weeks at a postal school following OBC. Other branches have similar follow-on courses to their basic courses.

Using this system, the Army trains newly accessed second lieutenants in approximately eight months. This varies among the different branches of the Army, with Aviation Officers requiring the longest amount of time (around 18 months). The above training does not include additional time if officers attend training other than their OBC, such as Airborne School, Air Assault School or Ranger School.

B. PROPOSED CHANGES TO ACCESSION TRAINING

The Commander of the Army Training and Doctrine Command (TRADOC) has directed a change to the current accession training system. The proposal introduces what TRADOC calls the Basic Officer Leadership Course (BOLC), which will replace the Officer Basic Course.

The BOLC has two phases. The first phase, called BOLC I, will teach officers from all branches of the Army the common core requirements of Accession Training. This includes subjects such as Army customs and courtesy, rifle marksmanship, land navigation, and common survival tasks required of all soldiers in the Army. BOLC I will take place at three locations: Forts Benning and Sill, and probably Fort Bliss. TRADOC currently plans to have BOLC I last 35 training days.

Phase One of BOLC is still in its planning stage, but throughout the course of my thesis development, TRADOC has distributed more information and shed light on some issues where I have had to make assumptions. TRADOC plans for 35 BOLC I offerings among the three different installations, approximately twelve at each site. Current plans show BOLC I with a max class size of 200 officers, and a minimum of 100 active duty officers per class.

After completion of BOLC I, second lieutenants will then proceed to Phase Two, aptly called BOLC II. This phase instructs officers on the same technical or branch specific training completed by the Officer Basic Courses. BOLC II will be held at the same installations that currently host the Officer Basic Courses, and the same cadre responsible for the branch specific OBCs will be responsible for BOLC II. In essence, BOLC II is just a new name for the Officer Basic Course; it is just shorter in duration.

The length of the different BOLC II courses in most cases will be equal to the length of the corresponding Officer Basic Course less six weeks. Aviation BOLC II only reduced the length of their technical training by two weeks, and Finance BOLC II, having an original OBC length of eleven weeks, could not reduce the course length by more than two weeks either.

Since this information from the different officer basic courses is dynamic, I have centralized the simulation’s input parameters, which increases its flexibility. The simulation takes almost all of its input from one file; manipulating a single element in this file will change the use of that parameter throughout the simulation.

If Finance BOLC II, TRADOC or any other agency readjusts any of their policies regarding BOLC, a simple, corresponding field manipulation in one file of the simulation will reflect the policy change throughout the simulation.

The figure on the following page captures TRADOC’s proposed accession training program with BOLC’s implementation.

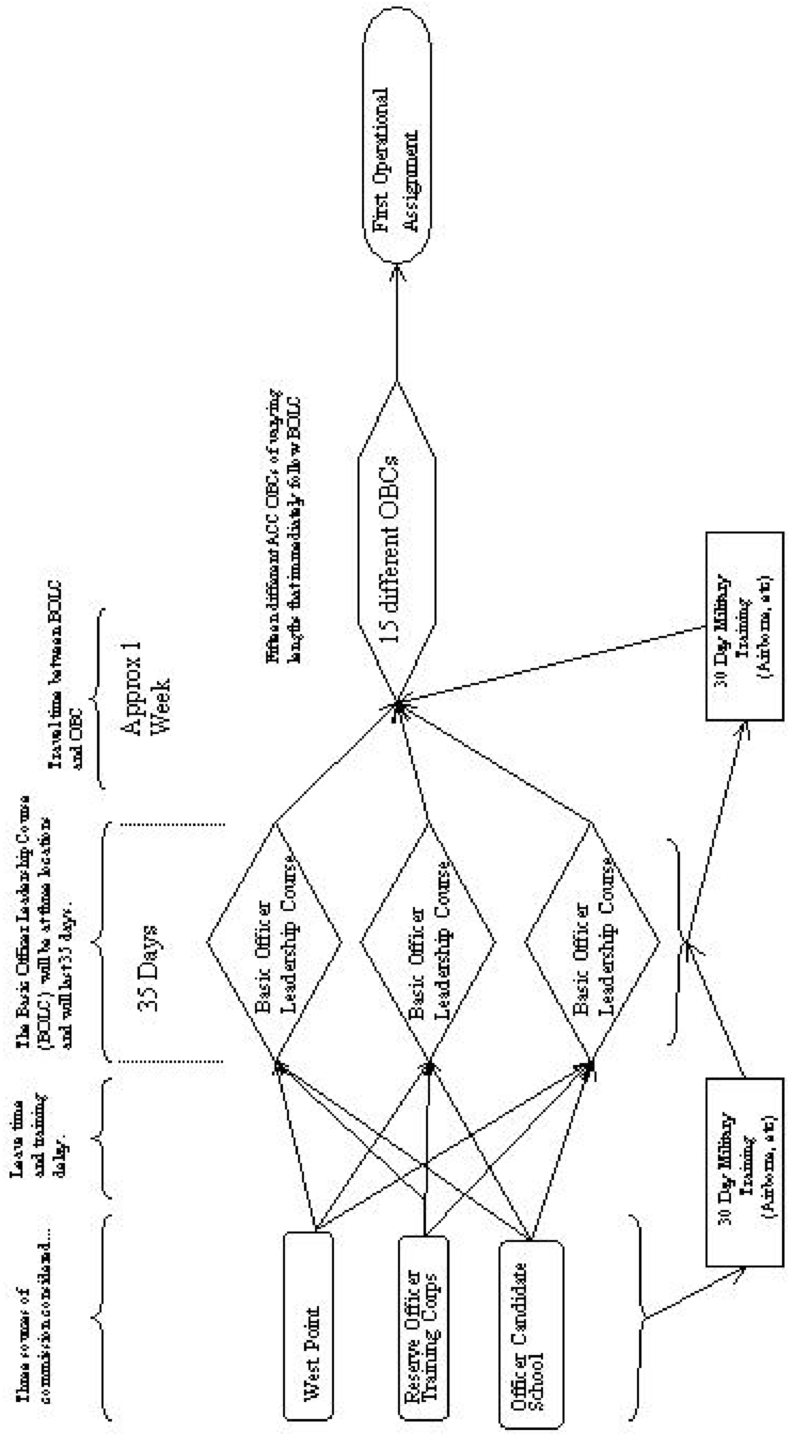

Figure 1. Accession Training System with BOLC Implemented

C. THE EFFECT OF THE BASIC OFFICER LEADERSHIP COURSE ON ACCESSION TRAINING

The manning of the Army falls under the staff supervision of the Deputy Chief of Staff, G-1. Army G-1 would like to determine the expected length of time officers from each branch spend in the Transient, Holdee, and Student (THS) account in a year, once BOLC is implemented. With the implementation of BOLC, there is concern that officers may have to wait longer for training to start. The unofficial term that the Army uses for officers who arrive early to a training site is “snowbirding”. Snowbird time does not include the travel time between installations. If snowbird time increases for officers, then the THS time will also increase.

The primary goal of my thesis is to determine the effect that the addition of BOLC to the accession training system will have on the Army’s THS account. I will also explore the effects that different proposed TRADOC policies relating to BOLC’s implementation will have on THS.

As with any large organization, the Army’s resources (dollars, manpower, time) are constrained. Any new initiative, such as BOLC, requires analysis to determine the cost associated with implementation. TRADOC asserts THS levels (a manpower resource) will not increase under BOLC (as compared to the current training system in place). Due to perceived scheduling inefficiencies, analysts within Army G-1 reject this notion, but need a tool to assist in analyzing the expected THS growth. To answer why THS growth is important, it is necessary to fully explain why the THS account is important.

1. The Importance of the Transient, Holdee and Student Account

The Army's divides its total strength into two sub-accounts – THS and Operational Strength (OP STR). The OP STR consists of all soldiers who are available to fill authorized unit positions, or "fill the foxholes", so to speak. By contrast, the THS account consists of the soldiers who, for various reasons, are unable to fill these positions. The Army has a congressionally mandated strength limit of 480,000 soldiers. Therefore, as THS grows, OP STR must decrease, resulting in a unit manning decrease as well.

The following categories or statuses define officers in the THS Account (Sweetser, 2000):

> Officer Accession Students – includes officer basic courses and all initial skill and proficiency training taken before travel to the officer's first permanent duty assignment. This includes the new BOLC requirement.
>
> Transient – loosely defined as officers who are moving between duty assignments.
>
> Holdee – officers that are dropped from the assigned strength of a force structure unit and attached to a "holding" facility because of medical, disciplinary or pre-separation non-availability.
>
> Student – officers that are attending non-initial entry courses of instruction in a permanent

change of station (PCS) status or in a temporary duty (TDY) status in conjunction with a PCS.

The Military Strength Analysis and Forecasting Division of the Army G-1 is responsible for capturing THS data and providing THS forecasts. On the last day of each month, the Army takes a statistical snapshot of the personnel database and records the duty status and demographic characteristics of each individual on active duty. This monthly record becomes another data point in the THS analysis the strength analysis team of DCSPER has refined and improved over several decades. The Army’s THS model, also called the Individual Account model, is based on historical behavior of Army personnel in the THS account(Sweetser, 2000).

Army G-1 utilizes exponential smoothing as a time-series forecast technique to provide an aggregate forecast (officer, warrant officer and enlisted) over the four categories mentioned above (Officer Accession Students, Transient, Holdee and Student) (Military Forecasting and Strength Analysis Division, May 2002). While factors such as course lengths and permanent change of station (PCS) budgets affect THS behavior, they are not parts of the THS model, per se. As these factors change the data that drives the model, analysts incorporate them into its output. There are several drawbacks to this model. First, the model does not get into the grade or rank level of detail. Second, when policy decisions are made that will affect the size of the THS account, such as a change in the accession training system, it is difficult to adjust model results to capture these effects.

The size of the THS account is a factor in the formulation of many Army personnel policies. One example is the plan that distributes officers to the force, or the Officer Distribution Plan (ODP). The analysis team that publishes the ODP uses the projected THS account strengths to help determine the number of officers available to assign to the major commands throughout the Army in upcoming years.

The Deputy Chief of Staff, G-3 and Army G-1 co-chair a task force named the Operating Strength Steering Committee, which dedicates itself to reducing the size of the THS account. The fact that two Lieutenant Generals have dedicated their time to THS gives some idea of its importance.

For the reasons above, THS modeling is an extremely important tool for Army personnel management. The introduction of a seven-week course into the officer training system will have an effect on the THS account. Quantifying this effect and translating the effect on manning the force is important in Army manpower management.

2. Modeling Approach

This thesis develops a simulation as analysis tool for the Strength Analysis Staff of Deputy Chief of Staff, G-1. I have implemented the model using Java and Simkit. The simulation runs for a specified number of accession years and captures every officer's attributes, to include the time they spend in the simulation's accession training system. Running the model will provide 4500 officer data elements per simulated accession year on which to conduct regression analysis.

The simulation model creates an accession training environment for newly commissioned second lieutenants to navigate prior to their first operational assignment. During the course of their training, officers are subject to attrition and recycling, and can conduct military training (Airborne or Air Assault School). Data for historical graduation rates and the projected accession training schedule are input into a simple text editor.

The output is a simple list of all the officers created by the system, with a record of their training as they completed the simulation. I export this list of officers to a Microsoft EXCEL spreadsheet, where a pivot table can organize the officers into different categories as necessary for further analysis. For more detailed statistical analysis, I export the EXCEL to a more powerful data analysis tool called S-PLUS.

Army G-1 can use the simulation results with their own on-going analysis to determine BOLC’s effect on the THS account and how it might affect certain specialties of officers.

D. RELATED RESEARCH

The fruits of my research determined that many more analysts use methods of optimization over simulation to solve this type of problem.

Hall (Hall, 1999) develops a mixed integer program to plan monthly training schedules for Army Basic Combat

Training, One Station Unit Training, and Advanced Individual Training. Her model maximizes the efficiency of the training schedule by minimizing the number of recruits held over, minimizes the annual soldier training requirements not met, and aspires to optimally fill all the courses. The output from the mixed integer program is a schedule for the courses listed above. Implementation of the schedule would result in an improvement of 1800 soldier-years in holdover time for soldiers. This is the equivalent of creating a brigade’s worth of manpower for the Army at no additional cost.

Grant (Grant, 2000) develops another linear program developed to decrease the time Marine officers wait for their military occupational schools to start. Rather than optimizing a schedule, as Hall did above, Grant’s model optimally distributes military occupational specialty quotas to all fiscal year Basic School companies. The quota distribution proposed by his model provides maximum equity of opportunity for all officers to seek any of the Marine’s twenty-one military occupational specialties and yields a total training time reduction as high as 45 man-years.

Chilson (Chilson, 1998) creates a mixed integer linear program to produce a schedule that reduces the time needed to assign newly commissioned ROTC cadets to their accession training locations. Implementation of the schedule for ROTC officers would result in a possible temporary duty cost reduction of $15 million.

Brown (Brown, 2002) is currently developing an optimization model that will determine the best seat allocation policy for enlisted soldiers in the Army Reserves attending active duty Initial Entry Training Courses.

Ulrich, assigned to the Distribution Development and Programs Branch of the Total Army Personnel Command (PERSCOM), (Ulrich, 2002) has developed and is currently using a manpower simulation to project inventory levels, by grade, over a thirty year planning horizon. The simulation has variable inputs such as attrition rates, promotion rates, promotion points and the number of accessions, which enable analysts to examine the possible effects of officer policy initiatives with an associated degree of certainty. The simulation is a spreadsheet, formulated and changed in EXCEL; it runs stochastically with an additional software extension (@RISK from Palisade). Typically, the simulation runs in approximately ten minutes while iterating 10,000 – 15,000 times. The output is the projected inventory, associated with different confidence levels, for each grade based on the model inputs and assumptions. Initially, the primary use of this model was to determine the available inventory used in the officer distribution process. With a thirty-year projection capability and stochastic inputs, analysts use this model more frequently to examine the effects of officer policy initiatives.

I have chosen simulation over optimization as the method to address this problem for one reason. Because TRADOC has not finalized many of the policies regarding BOLC’s implementation, I need the flexibility a simulation gives to design an experiment specifically around the key, unknown policies and determine how they might individually or in combination impact accession training time.

Optimization would be a better option for this thesis had TRADOC distributed firm policies regarding the changes to accession training. The uncertain nature of TRADOC’s policies gives no hint to the best functional representation of this system. My lack of foresight into the new accession training system coupled with the need to thoroughly explore wide ranges of policy implementations lead me to believe that simulation is the better alternative for this problem.

With the completion of this thesis, I will be able to model the system using response surface models. Once the functional form is known, then any follow-on analysis could use optimization to recommend optimal policy settings to TRADOC.

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II. MODEL

A. PROBLEM STATEMENT

The Military Strength Analysis and Forecasting Division of the Deputy Chief of Staff, Army G-1 needs an analytical tool to help determine the effect that TRADOC's implementation of BOLC will have on the THS account.

B. EVENT GRAPHS

My simulation is built around an event graph. Event graphs are a way of graphically representing discrete-event simulation models (Schruben, 1983). The event graph provides the logical and algorithmic skeleton around which a discrete event simulation is built. To understand the Accession Training simulation model, one must understand its underlying event graph. For the rest of this section, I will borrow heavily from the ideas presented in "Basic Event Graph Modeling" (Buss, April 2001) to familiarize the reader with event graphs.

My simulation uses Simkit, software developed at the Naval Postgraduate School (Buss, November 2001). Simkit is a set of JAVA packages that support the construction of discrete-event models. There are three fundamental components to a discrete event simulation, a set of state variables, a set of events, and a list of pending events.

The measures of performance for the simulation are functions of the state, which is represented programmatically as a set of state variables. As the simulation progresses in time, it generates the state trajectories, or the time history of successive values of the system’s state variables.

State trajectories are piecewise constant in discrete event models. Events in the simulation occur at points of time when at least one state variable changes value or an event gets scheduled. An event in the discrete event simulation is instantaneous; no simulated time passes when an event occurs, only between the occurrence of events.

The timing for the occurrence of these events is controlled by the event list. Think of the event list as a “to-do” list of scheduled events. Whenever the simulation schedules an event, it is placed on the event list with two pieces of information. The first is the identification of the event. The second is the time at which the event is scheduled to occur. The event list determines the event with the lowest scheduled time. Events that occur simultaneously are prioritized in some logical manner determined by the model designer’s knowledge of the real system. The SIMKIT software manages the event list and the state trajectories for the programmer.

Event graphs are a way of representing the event logic for the discrete-event simulation. An event graph consists of nodes and directed edges. Nodes correspond to events or state transitions, and edges correspond to the scheduling of other events. Figure 2 below depicts a basic event graph.

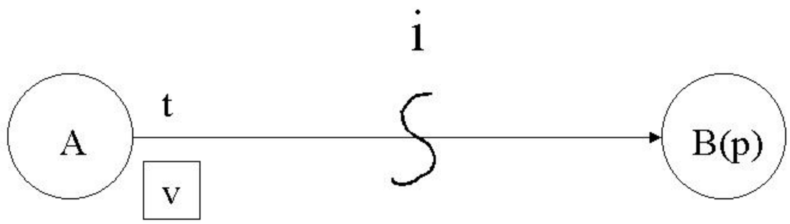

Figure 2. A General Event Graph for Explanation

The interpretation of the event graph in Figure 2 is that the occurrence of Event A causes the scheduling of Event B after a time delay of **t**, providing condition **i** is true after the simulation performs the state transitions for Event A. Event A also creates and passes a value **v** to Event B. Event B uses the value to set a parameter **p**, and incorporates it by the logic defined within the event.

By convention, the time delay **t** is indicated toward the tail and above the scheduling edge. If the event graph does not specify a delay, it is zero. The value that is passed is identified below the edge, directly under the time delay and placed in a square, and the edge condition is shown just above the wavy line through the middle of the edge.

The value **v** on the scheduling edge is resolved at the time Event A occurs. In Event B, **p** is actually a formal parameter. Think of the value as a “time capsule”, or a means of passing information about the current state of the model to a future event.

With these basic concepts of event graphs explained, I will proceed to the events graphs specific to my model. These event graphs subscribe to the conventions described above excluding the edge conditions. I explain the edge conditions fully in the text; removing them from the event graphs improves their readability and simplicity and also reduces redundant information for the reader.

C. ACCESSION TRAINING EVENT GRAPHS AND DISCUSSION

The model for my simulation breaks accession training into four distinct areas: Accession, BOLC, OBC, and Operational Assignment. I will describe each of these four areas as a whole, and then in separate sections detail the specific events in the simulation that fall under each of the above four categories.

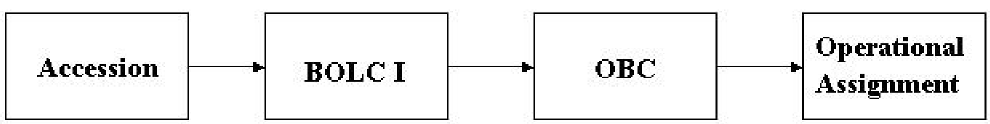

Figure 3. Simulation Breakdown

As stated above and seen in Figure 3, I have divided accession training into four distinct areas. Although a newly commissioned officer can do many different types of training, those listed are the most important to the officer and the only ones used in the model.

Figure 3 also shows how the parts of the simulation interact with each other. According to the figure, the

BOLC portion of the simulation "listens" to the **Accession** portion; "listening" is another way of saying that **BOLC** waits for **Accession** to schedule an event that has exactly the same name as one of its own events. If **Accession** schedules an event that it and **BOLC** both share, they both will act on the event call as the logic within their own events dictate. Just as **BOLC** listens to **Accession**, **OBC** listens to **BOLC** and **Operational Assignment** listens to **OBC**. This creates a modular design for the software.

Accession is the point where an officer enters Army. The Army gets almost all of its ACC officers from three primary sources: The United States Military Academy, the Reserve Officer Training Corps, and the Officer Candidate School. The Accession portion of the simulation creates officers on specific historically based "graduation" dates. After the model generates the officers, they are ready to move to their first training assignment, BOLC.

The Basic Officer Leadership Course is the change to the training system that I am studying. Fort Benning, Fort Sill and Fort Bliss will host BOLC in the simulation. While at the course, officers may undergo attrition or recycle to the next start date of BOLC. Once officers have completed the BOLC portion of the simulation, they proceed to OBC.

I have refrained from using TRADOC's new phrase for OBC. TRADOC now calls the Officer Basic Course "BOLC Phase Two", or BOLC II. To keep the names of the courses distinct, I will use OBC instead of BOLC II. This naming convention made the program code more distinct between the different training areas, and I believe easier for the reader to distinguish between the BOLC phases in my discussion.

The Officer Basic Course section of the simulation is where officers receive their technical training. I have reduced the course lengths of the OBCs to reflect each individual school's projected course length upon BOLC's implementation. As in BOLC, an officer may suffer attrition or have to recycle to a later course offering. Once OBC is complete, officers in this simulation proceed to their operational assignment.

For potential expansion of the simulation, I explicitly created this last portion, the Operational Assignment. I could have stopped the simulation once an officer completed OBC and mathematically received the same output. However, forcing officers to arrive at their operational assignment without delay will allow me to add training events to the simulation.

For example, if I wanted to add Airborne School as a distinct and separate portion of this model, I can leave open the possibility that an officer would go to Airborne training after OBC. After leaving OBC and then completing Airborne School, the officer would then travel to the Operational Assignment portion of the simulation. This modeling strategy forces all officers, excluding those who suffer attrition, to end in the same part of the simulation. Furthermore, it allows me to easily expand the model.

1. Accession

As alluded to in previous sections, the model begins with Accession. This section creates the officers that will later pass through the events further in the simulation. The actual event graph for Accession is in Figure 4 below.

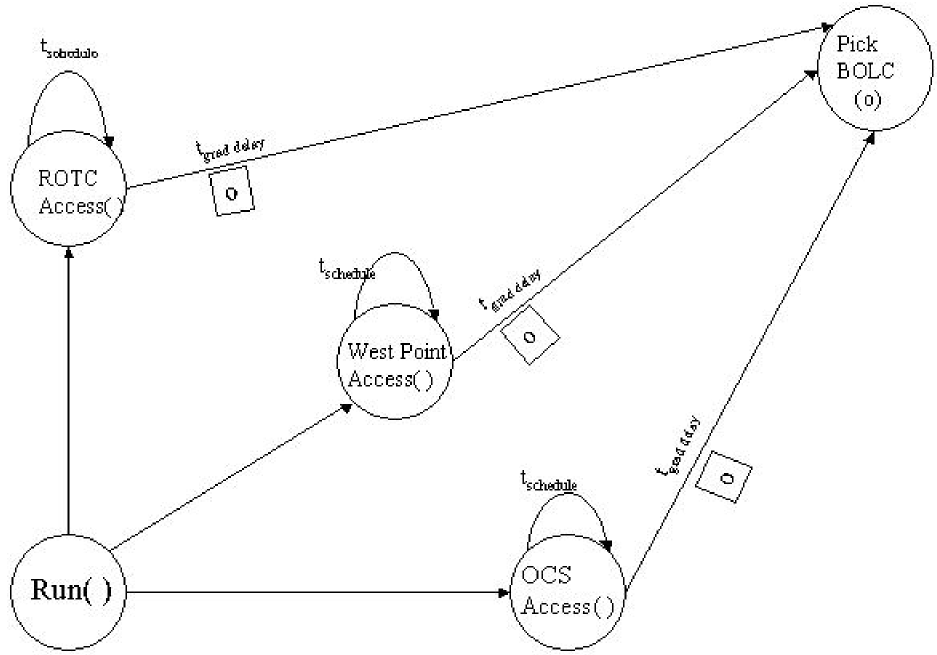

Figure 4. Accession Event Graph

The simulation starts with the first event called **Run()**. With this event, the model schedules the graduations for West Point, ROTC and OCS. The graduation data, to include graduation dates, branch commissioning ratios and graduation delay rates are listed explicitly in Appendix A. The **Run()** event takes the graduations dates from the three sources of commissioning and places them on the simulation schedule. This event schedules graduations for a certain number of years as directed by the user.

After the **Run()** event has placed the accession dates on the event list, the simulation will move to the first graduation event. It may be one of three graduation events, either a West Point, ROTC or OCS graduation, depending upon which graduation is the first on the event list. As the simulation progresses, it will continue to conduct the graduation events as dictated by the schedule.

The **OCS Access()** and the **ROTC Access()** events are identical, with their input parameters the only difference. I received the input parameters for OCS graduations from Accessions Branch of PERSCOM (Rolland, 2001) and the ROTC input data from the Accessions Branch (Lindeman, 2001), ROTC Cadet Command (ROTC Cadet Command, 2001) and the Officer Strength Analysis Staff, Deputy Chief of Staff, Army G-1 (Military Forecasting and Strength Analysis Division, March 2002).

For the upcoming paragraphs, I will discuss the **OCS Access()** event with the knowledge that the same logic and reasoning applies to the **ROTC Access()** event.

The input for OCS graduations includes historical data on the minimum percentage of officers from OCS that graduate into certain branches of the Army in a fiscal year. The **OCS Access()** event multiplies this minimum percentage for each branch to the total number of graduates for that scheduled OCS graduation. The result is the minimum number of officers from each branch of the Army that will graduate upon the completion of OCS.

With the minimum branch assignments calculated for the graduation, the simulation will need to assign the remaining officers a branch based on the same historical data. The number of remaining officers for each branch is not deterministic; instead, historical data shows that the percentage of officers going to different branches varies from graduation to graduation and from year to year.

The simulation embraces the variable nature of graduation branch assignments and includes it in the model. The historical data also includes a possible maximum percentage for each branch of a graduation. The **OCS Access()** event takes this maximum possible percentage for each branch and multiplies it to the number of officers that will graduate in the OCS course. This value is the maximum possible number of officers that can graduate from each of the fifteen branches.

Subtracting the minimum number of officers from each branch that the simulation calculated earlier from this maximum number of officers gives the greatest number of officers for each of the branches that could be in the remaining number of officers not assigned a branch. Scaling this difference between the maximum and minimum officers for each branch by the total number of remaining officers who need a branch assignment, results in a probability that any one officer in the remainder will be from a certain branch.

With these probabilities, the simulation iterates through the officers not assigned a branch. With each iteration, the simulation calculates the probability of assignment to each of the fifteen branches, and creates a cumulative distribution function (CDF). After the CDF is in place, the simulation generates a uniform random number between zero and one, and where that random number falls into the CDF dictates what branch the officer will receive.

Knowing the branch for the officer, the model creates a new officer, recording the accession date and fiscal year, the branch, the source of commission, and initially assigns them to a BOLC location based on minimizing its distance from the BOLC location to the officers' OBC.

When the simulation creates the officer, one characteristic it must determine is whether or not the officer receives an immediate active duty (IA) commission. West Point and OCS graduates automatically receive IA commissions, which means they count against the THS account immediately upon graduation. Graduates from an ROTC program do not automatically receive an IA commission; in fact, only approximately half of them receive immediate active duty status. An ROTC graduate who does not receive an IA commission does not receive pay or count against the THS account until they arrive at their first training site in the accession training system.

To determine the IA status of newly commissioned officers, the simulation notes the source of the officer's graduation. By default, the simulation assumes the officer is an immediate active duty officer. If the check reveals that the officer is a ROTC graduate, the simulation draws a uniform random number between zero and one. The model assigns the ROTC officer and IA commission if the random number drawn is less than the ratio of ROTC officers who receive an IA commission. If the officer does not receive the IA flag, its THS clock will not start until they arrive at their first training location.

With this officer instantiated, the simulation schedules the next event on the Accession event graph called **Pick BOLC()**. The officer with all recorded data is passed as a parameter to the **Pick BOLC()** event with a random delay time based on historical data. The simulation then recalculates the branch probabilities, subtracting one from every branch’s denominator (the total remaining officers needing a branch assignment) and subtracting one from the numerator of the branch that just had an officer receive an assignment to its specialty. This process continues until all of the officers without an initial branch assignment receive one and get scheduled for the **Pick BOLC()** event.

With the remaining officers assigned to branches and scheduled for the **Pick BOLC()** event, the simulation now must create the officers that had previously been identified for meeting the minimum branch requirements for the graduation. The model, in a random order among all of the branches, creates these minimum number of officers for each branch in the same manner mentioned above and schedules them with the random delay times for **Pick BOLC()**.

The **West Point Access()** event differs from the **OCS Access()** and **ROTC Access()** events only in the way the simulation assigns the delay times after commissioning. Where OCS and ROTC grads have an almost continuous and wide spread delay time, West Point graduates typically have four different categories of delay. Graduating West Point cadets have the option to take 30, 60 or zero days of leave. Some graduates also serve as assistants to one of the West Point varsity athletic teams for 180 days. The 30, 60 and zero categories translate into actual graduation delays of 15, 45 and 75 days, due to travel time to their first training event. The West Point S-1 provided the West Point graduation delay information (Vonasek, 2002). The West Point liaison to the Deputy Chief of Staff, Army G-1 provided the remaining historical West Point graduation data for the simulation (Beans, 2001). Using the graduation delay data, I created a triangle distribution representing the minimum, maximum and average percentages of the West Point classes that take any of the four different types of leave after graduation.

The **West Point Access()** event uses the same approach to assign West Point officers their delay as the simulation uses to assign all officers their branch specialties. The paragraphs that discuss the **ROTC Access()** method cover this approach thoroughly. The **West Point Access()** method first insures that the minimum requirements for each category of delay are met by multiplying the graduating class size by the minimum percentages in each of the different categories of delay. The result is the minimum number of West Point officers from that graduating class that will assume each category of delay. The model completes the same calculation using the maximum percentage for each category. The result is the maximum possible number of West Point officers that can assume a certain category of delay.

The simulation then subtracts the minimum number of officers from the maximum number, and constructs a CDF for each iteration through the officers not assigned a category of delay. The simulation stores the calculated categories of delay in a random order in a list and removes them one at a time as it creates officers in the **West Point Access()** event.

Inside the Accession portion of the simulation, **Pick BOLC()** is an "empty event", which means there is no code in the event other than to identify it. However, the event's presence is the trigger that starts the next step of the simulation, BOLC.

2. BOLC

The BOLC portion of the simulations holds all of the events associated with the Basic Officer Leader Course, Phase One. The event graph for BOLC is below in Figure 5. Note that this event graph shows the events for only one BOLC. The event graph would look exactly the same for all installations hosting BOLC; for simplicity I created one.

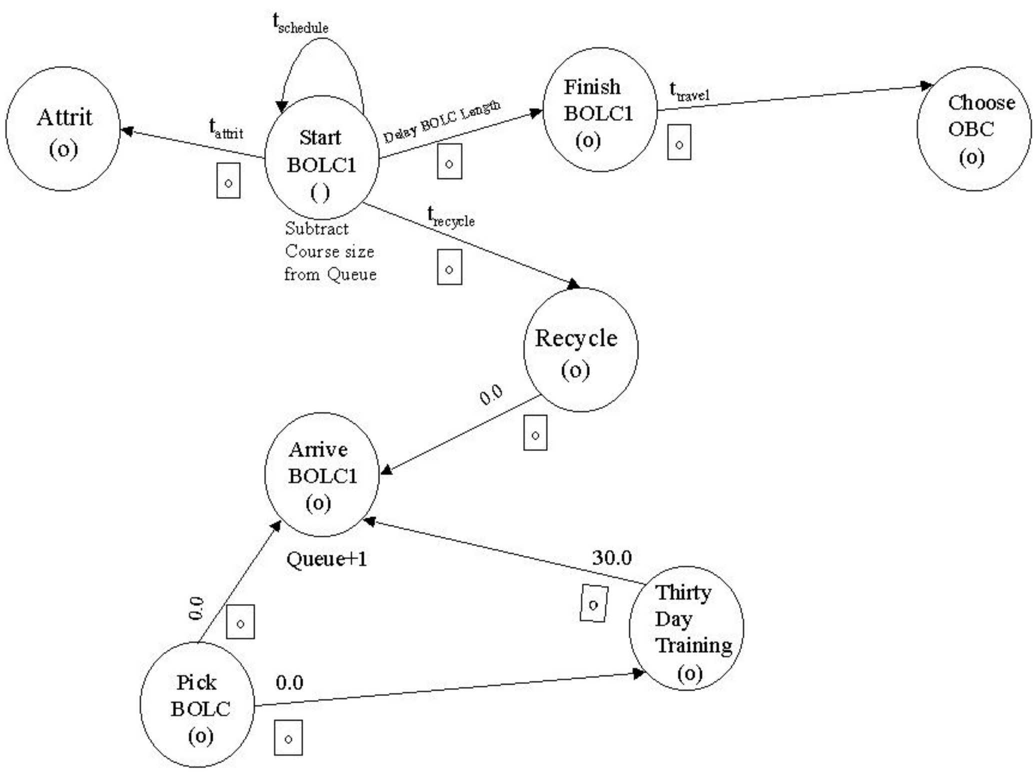

Figure 5. BOLC Event Graph

The **Run()** event in BOLC actually takes place at the same time as the **Run()** event in the Accession portion of the simulation. When the simulation starts, SIMKIT searches all portions of the simulation for **Run()** events and executes those first. This allows the programmer to set initial conditions for the simulation.

In the case of BOLC, the **Run()** event places all of the BOLC start dates for each of installations on the event list out for the number of years directed by the user. The BOLC schedules and all other BOLC data are in Appendix B.

After the **Run()** event, there is no activity in the BOLC portion of the model until an officer is scheduled for the **Pick BOLC()** event in the Accession portion. Since the BOLC portion of the simulation is waiting for the **Pick BOLC()** cue from the Accession portion, it immediately takes the officer parameter passed to it and continues with the simulation.

The **Pick BOLC()** event receives the officer parameter and prepares to permanently assign a BOLC. When the Accession portion created the officer, it initially assigned the officer to a BOLC based on the installation that is closest to the officer's OBC location. This strategy will help minimize travel time and costs. However, this tentative assignment might change for the officer based on two constraints.

The first constraint the officer must meet relates to the class size of the BOLC that they want to attend. TRADOC has not formalized their plans regarding maximum class sizes for BOLC, and I will explore this policy in my model. Before the officer can actually go to the BOLC to which they were initially assigned, the course must be less than the value set in the experiment design.

The second constraint that must be met is the time until the start date of the BOLC. The officer's BOLC start date must be less than thirty days from the time the officer ends graduation delay. Otherwise the officer would incur a large amount of snowbird time.

If the officer's initially assigned BOLC satisfies the above constraints, the model creates an **Arrive BOLC()** event for the officer.

There is the case in which the initially assigned BOLC does not meet the above two constraints. In such cases, the model searches the next three earliest BOLCs on the event list, and checks them for the same constraints. The officer is sent to the earliest of the three BOLCs to meet the above to criteria.

If one of the three BOLCs satisfy the class size constraint but fails the time until the start date constraint, the simulation assigns the officer to the partially satisfying BOLC but sends the officer to a **Thirty Day Training()** event first. The **Thirty Day Training()** event aggregates all additional training an officer might attend while conducting Accession Training. This additional training might include Airborne or Air Assault School. This event allows officers to take some beneficial training rather than sit around at the BOLC installation waiting for the next course start. The officer will "train"/delay for thirty days before entering the queue at the **Arrive BOLC()** event.

The **Arrive BOLC()** event receives officers from the **Pick BOLC()** event, the **Thirty Day Training()** event, or the **Recycle()** event. Once the officer arrives, the model places the 2LT in the queue and records the time the officer arrived. The simulation places an officer arriving from the **Recycle()** event at the front of the queue. Other wise, the model adds officers to the end of the queue until the next event, **Start BOLC()**.

A schedule created before the start of the simulation determines the actual start times for the **Start BOLC()** events. As stated above, these events were placed on the event list in the **Run()** event at the start of the simulation according to that schedule. The **Start BOLC()** event will not begin until the simulation reaches its predetermined start time.

The **Start BOLC()** immediately queries its queue from the **Arrive BOLC()** event to determine the number of officers waiting. If there are none, the course is cancelled without any statistics or state variables altered.

If the queue size is less than the minimum BOLC course size, the model will reschedule the **Start BOLC()** event for a time seven days in the future with the hopes that more officers will arrive in the queue. After the simulation reschedules the BOLC twice without meeting the minimum course size constraints, it cancels the course and the officers snowbird until the next **Start BOLC()** event on the event list.

If the queue size meets the minimum course requirements, the model takes up to the maximum course size out of the queue. The simulation then generates a recycle rate and an attrition rate.

I talked to individuals in the training staff at all fifteen Army Competitive Category Officer Basic Course schools. These personnel provided their estimates on the maximum, average and minimum recycle and attrition rates for their specific OBC. I transformed their data into triangle distributions. Since TRADOC has not yet implemented BOLC, I assumed that its recycle and attrition rates would be that same as those of the Infantry Officer Basic Course.

Using the Infantry Officer Basic Course (IOBC) rates, I scaled these values down to reflect the fact that BOLC is 35 days long, where IOBC is 112 days long.

Using these scaled attrition and recycle rates in a triangle distribution, the simulation generated an attrition and a recycle rate for that specific course. For each officer taken from the queue, the simulation generated an independent pseudo-random number from a uniform distribution between zero and one. If the uniform random number was less than the generated recycle rate, the simulation scheduled the officer for the **Recycle()** event. Since the officer may be recycled at any time in the course, the simulation generates another uniform random number between zero and one and multiplies it by the course length of BOLC. After rounding the number to an integer value, the model delays the officer for this length of time before actually putting **Recycle()** on the event list.

The Army would rather recycle an officer than release him or her from service. Since the model checks the recycle rate first, it gives recycling priority over attrition.

If the uniform random number passes the recycle rate test, the simulation tests the same random number against the sum of the attrition rate and the recycle rate. If the uniform number is less than that sum, the model schedules the officer for the **Attrition()** event, generating delay in the same manner as the **Recycle()** event.

If the uniform random number is higher than both the recycle and attrition rates, the simulation records the start time for that officer before passing it as a parameter to the **Finish BOLC()** event after a delay equal to the course length of BOLC.

As stated above, an officer may have to recycle. In the **Recycle()** event, the simulation records the recycling, and then schedules the **Arrive BOLC()** event where the officers enters the front of the queue.

In the **Attrition()** event, the model records the attrition, its time, and the total time the officer spent in the Accession Training system.

After passing through the **Start BOLC()** event without suffering attrition or recycling, the officer arrives at the **Finish BOLC()** event. This event schedules the officer for the **Choose OBC()** event, with a delay equal to the travel time between the BOLC installation, and the officer’s OBC installation.

Inside the BOLC portion of the simulation, **Choose OBC()** is an “empty event”, which means there is no code in the event other than to identify it. However, the event’s presence is the trigger that starts the next step of the simulation, OBC.

3. OBC

The OBC portion of the simulation holds all of the events associated with Phase II of the Basic Officer Leadership Course. The OBC event graph is below in Figure 5. As in the BOLC event graph, I present one event graph to represent the event graphs for the fifteen different OBCs in the Accession Training System. The events for all fifteen of the OBCs are exactly the same; for ease of presentation I will show one event graph.

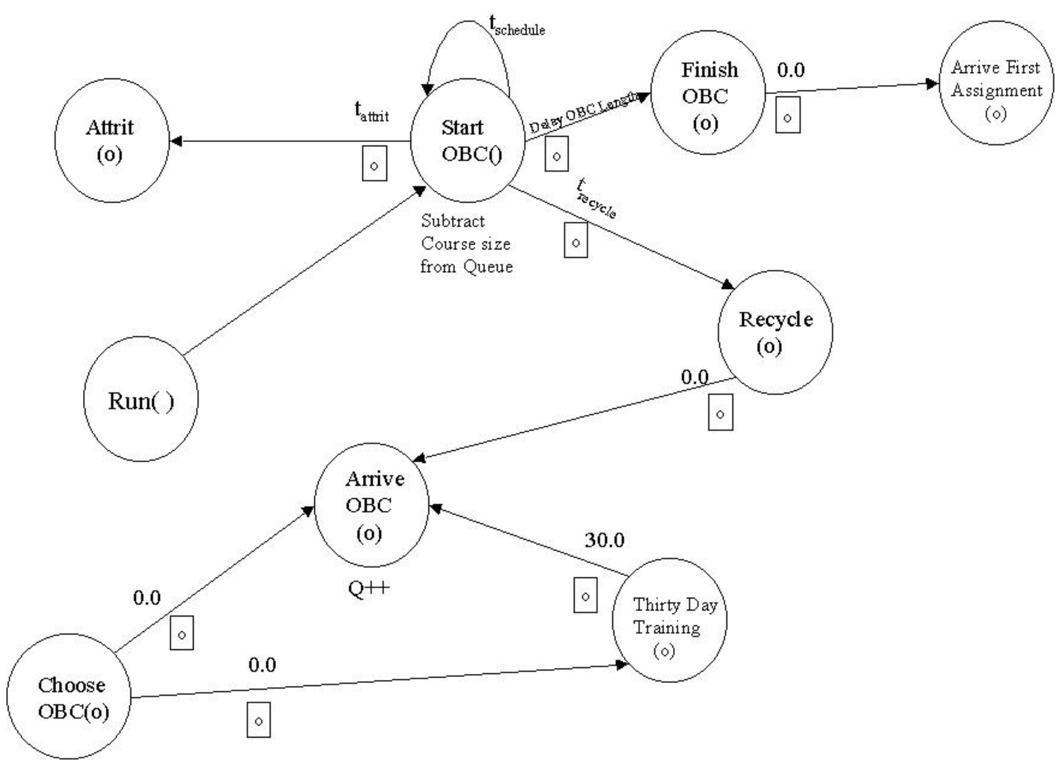

Figure 6. OBC Event Graph

The OBC portion of the simulation is almost identical to the BOLC in terms of event logic and officer flow.

There is a **Run()** event in OBC that places the start dates for all of the officer basic courses on the event list at the very beginning of the simulation. These times represent the points in the simulation where the **Start OBC()** events will occur. The **Start OBC()** event will not run until the times designated by the **Run()** event. The start dates for OBC courses and all OBC data for the simulation is in Appendix C.

Since the OBC portion listens to the BOLC portion, it runs the **Choose OBC()** event when BOLC sends an officer parameter to the **Choose OBC()** event in its portion. In the OBC part, the **Choose OBC()** event looks at the officer parameter passed to it and identifies its branch of the Army. With this identification, the simulation knows to which OBC it must go.

Before it schedules the **Arrive OBC()** event for that particular officer’s branch, it checks the event list to determine when that officer’s OBC will start. If the start time is more than thirty days away in the simulation, the **Choose OBC()** event places a **Thirty Day Training()** event on the event list, and the officer goes there with zero delay. If the start time is thirty days or less away, the simulation schedules the officer for its branch’s **Arrive OBC()** event with zero delay.

The **Thirty Day Training()** event serves the same purpose and has identical logic in the OBC portion of the simulation as it does in the BOLC portion.

The **Arrive OBC()** event can receive an officer parameter from one of three events: the **Choose OBC()** event, the **Thirty Day Training()** event, and the **Recycle()** event.

If the officer parameter comes from the **Recycle()** event, the simulation places the officer at the front of the queue. Otherwise, the officer will go to the end of the queue. In all cases, the **Arrive OBC()** event records the time of arrival for that officer parameter.

At the appropriate time in the event list, the **Start OBC()** event initiates. This event queries the size of its particular queue. If there are no officers waiting to take the course, the simulation cancels the course with no state variables altered.

If there is at least one officer, but less than the number required to start the course, the **Start OBC()** event will place another **Start OBC()** event on the event list with a seven-day delay. The simulation will reschedule an OBC at most three times before canceling it. The officers in the queue will snowbird until the next course offering.

Once an OBC meets the minimum course size requirement, the **Start OBC()** event removes from the queue the number of officers up to its maximum course size. If the number of officers in the queue is greater than the max course size, the extra will wait until the next course offering.

The **Start OBC()** event schedules **Recycle()** and **Attrition()** events in the exact same manner as the **Start BOLC()** event in the BOLC portion of the simulation. The only difference is each of the fifteen OBCs has a distinct recycle and attrition rate. Furthermore, the **Recycle()** and **Attrition()** events themselves are logically equivalent in both portions.

If an officer does not recycle or suffer attrition, the model notes the OBC start date, delays the officer for a time equal to the length of the OBC, and passes the officer as a parameter to the **Finish OBC()** event.

The **Finish OBC()** event receives the officer parameter, notes the time the officer completes OBC training, and schedules an **Arrive First Assignment()** event for the officer with zero delay.

The **Arrive First Assignment()** in the OBC portion of the simulation is an empty event. There is a similarly named event in the Operational Assignment portion of the simulation that is listening to the OBC portion. This event is the link for the officer between the OBC and Operational Assignment sections of the model.

4. Operational Assignment

This portion of the simulation has one event, and the event graph is trivial. The single event in this section is the **Arrive First Assignment()** event, and it receives the officer parameter from the OBC portion.

With the reception of the officer parameter, the **Arrive First Assignment()** annotates the time the officer arrived and records all of state manipulations that occurred for the officer throughout the course of the simulation.

D. SIMULATION VALIDATION

Military Strength Analysis and Forecasting Division of the Deputy Chief of Staff, Army G-1 validated my model. I provided them the event graphs and their logic from this chapter. Their approval of my model design validates the simulation and the results I obtain through it. (Yamada, 8 May 2002).

For further validation, I created a simulation separate from the event graph methodology developed above that represents the current accession training system, which is without BOLC’s implementation. The logic of the Accession and OBC portions was the same, but the input parameters for OBC were different as they reflected course lengths for an accession training system without BOLC. I ran the simulation and noted the time officers spent in the THS account.

I sent this data to Deputy Chief of Staff, Army G-1 Military Forecasting and Strength Analysis Division to insure this output was comparable to the values they see when they conduct their analysis of the current Accession Training system.

The results of the validation model are in Table 1 below. This output met the approval of the aforementioned analysis agency (Yamada, 24 April 2002).

Table 1. Validation Model Results

Officer Branch	**Average days of THS time**	**Standard Deviation**
All Officers	*186.02*	*39.93*
Adjutant General Officers	174.88	36.02
Finance Officers	164.07	49.11
Infantry Officers	183.04	34.76
Field Artillery Officers	214.77	38.60
Armor Officers	184.12	46.70
Air Defense Officers	204.50	47.58
Aviation Officers	230.01	53.40
Engineer Officers	172.93	40.84
Military Police Officers	166.67	39.32
Chemical Officers	207.10	42.17
Military Intelligence Officers	185.28	28.56
Signal Corps Officers	172.59	26.99
Quartermaster Officers	167.80	33.23
Ordnance Officers	191.24	38.77
Transportation Officers	171.28	41.89

E. ASSUMPTIONS

- Attrition and recycle rates for BOLC I will equal those from Infantry OBC.
- Other Army resource requirements (cadre requirements, billeting for officers, money, etc.) are not a factor.
- Fort Bliss will be the third installation hosting BOLC Phase One.
- The probability of an officer suffering attrition or recycling is equal across all days of any specific course.
- Recycle and attrition rates for a given course are directly proportional to its length.
- Attrition rate is per officer.
- Officers will not suffer attrition nor will they recycle during the **Thirty Day Training()** event.

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III. EXPERIMENTAL DESIGN

With the model completed, I designed an experiment for the simulation that tests TRADOCS's uncertain policy decisions relating to the implementation of BOLC. In addition to the controlled factors, there are uncontrollable variables in the system, primarily dealing with officer attributes. Since they are uncontrollable, I do not consider them in the physical design, but I will try to account for the variability they may cause using a robust experiment design on the simulation output.

I explain the controllable factors and their levels in the next section. I detail the specific experiment design using these factors in Section B.

A. EXPERIMENT FACTORS AND LEVELS

The following paragraphs describe the experiment's factors and their levels; they represent unpublished policies TRADOC might implement and one accession policy that I believe has an effect on the size of the THS account.

1. BOLC Branch Ratio Restriction

Training and Doctrine Command has not published a policy regarding any restrictions on the consistency of each BOLC class. Military Forecasting and Strength Analysis Division, Deputy Chief of Staff, Army G-1 speculates that TRADOC will enforce a policy that constrains the number of officers of any one branch that make up a BOLC class.

For example, if a BOLC class had 150 officers, and TRADOC had a BOLC Branch Ratio Restriction policy of 0.5, then that class could at most have 75 officers from any one branch of the Army. The policy set at 0.85 is the high level for this factor setting. The low setting is 0.55.

2. Minimum OBC Course Size Requirement

Initial analysis released by TRADOC has shown that they are considering allowing OBCs to start a course without any restrictions on their minimum course size. The Military Forecasting and Strength Analysis Division feels this is an unrealistic relaxation of the problem.

To determine the significance of this relaxation, my experiment design includes a binary factor where OBCs may start with as few as one active duty officer waiting in the queue. This is the low setting for the factor. The high setting places historical restrictions on the minimum number of officers needed to start a course. The traditional minimum course requirements of OBCs are in Appendix C.

3. BOLC Minimum Course Size or Difference Between Maximum and Minimum BOLC Class Size

Training and Doctrine Command plans to train 7000 officers per fiscal year in BOLC. This number includes active duty, National Guard, Reserve and officers from other countries. Active duty officers make up 4500 of the total. With no historical data present, and no policy in place, the experiment will explore the minimum number of active duty officers that must be present for a BOLC to begin. The experiment uses a minimum of 50 officers required to start a BOLC for the low setting, and it uses a minimum of 100 officers to start a BOLC for the high setting.

During regression analysis, I will use this information in a factor called Difference Between Max and Min Course Size will provide more insight into the model than just the Min BOLC Class Size. The simulation design required a minimum class size for proper execution; the model will capture this information in the new factor.

4. BOLC Maximum Class Size

Training and Doctrine Command has released the fact that they plan to have a 200-officer maximum course size for BOLC. However, they go on to say that the course can surge to 250 officers if needed. The problem here again is that this number of officers includes National Guard, Reserve and foreign officers. Training and Doctrine Command has not addressed how active duty participation requirements, if any, will figure into this policy.

The experiment explores the effect of this maximum course size on the total THS time. I have taken the ratio of active duty officers to total officers training in BOLC in a fiscal year, 4500/7000, and multiplied that value to TRADOC’s planned normal capacity for a BOLC class, 200 officers. The result is approximately 129, or the expected number of active duty officers in a BOLC class with a size of 200. This assumes that active duty officers are uniformly distributed across all BOLCs, which is not reasonable.

To explore the effect that the factor of maximum BOLC class size will have on total THS time, the experiment establishes 150 officers as its low setting, and 250 as its high setting.

5. Immediate Active Duty Ratio

The immediate active duty ratio represents the percentage of a fiscal year’s commissioned ROTC officers that receive active duty status immediately upon graduation. This factor is important because those ROTC graduates that do not receive IA status do not enter the THS account until they arrive to their first training site; officers with IA commissioning count against the THS account congruent with their accession date.

The ratio of IA to those ROTC graduates not receiving an IA commission varies from year to year, but historically is around 50 percent. My experiment explores how this policy’s setting effects total THS time. The two settings the experiment uses for the immediate active duty ratio are 0.40 for the low, and 0.60 for the high.

Of all of the factors listed above, this is the least controllable. There are many different types of information that ROTC Cadet Command takes into consideration when finalizing this policy for a fiscal year. Two of these are budget constraints and manpower goals. It is included as a controllable variable for this analysis to show its impact on the THS account and how important this policy is to the accession training system.

The table on the following page summarizes the five controlled factors and their settings used in the experiment.

Table 2. Summary of Controllable Factors and Their Levels

Factor	***High Setting***	***Low Setting***	***Center Setting***	$\sqrt{4}$ ***Setting***	$-\sqrt{4}$ ***Setting***
BOLC Branch Ratio	0.85	0.55	0.70	1.00	0.40
Min OBC Course Size Requirement	Required	Not required	NA	NA	NA
Minimum BOLC Course Size	50	100	75	125	25
Maximum BOLC Course Size	250	150	200	300	100
Immediate Active Duty Ratio	0.6	0.4	0.5	0.7	0.3

The following section explains the importance of the level settings.

B. REGRESSION EQUATION

The previous section described the factors whose effects on the THS account I wish to explore. Assuming that all of the factors and up to second order two-way interactions are potentially significant to the accession training time for 2LTs, my starting regression equation is the following, where TTT is the total training time:

y = Mean(TTT) & Var(TTT)(explained in a later section)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{15}X_1X_5 + b_{23}X_2X_3 + b_24X_2X_4 + b_{25}X_2X_5 + b_{34}X_3X_4 + b_{35}X_3X_5 + b_{45}X_4X_5 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2$$

After completing the first regression analysis using the model above, I will remove those factors and/or interactions from the regression equation whose p-value is greater than .05. However, if a factor has a p-value greater than .05, but is part of an interaction with a p-value less than .05, then it will remain in the regression equation. To obtain data for the regression analysis, I used a gridded factorial experiment design (Box, Hunter and Hunter, 1978).

C. GRIDDED FACTORIAL EXPERIMENT DESIGNS

A full factorial experiment for this simulation would create a large number of design points. For example, I want to explore TRADOC's potential policy on the maximum BOLC class size. Each BOLC class size might be as high as 250 officers, or as low as 150 officers. The range of this factor's setting alone (even if I select setting increments of five or ten officers apart) will drive the number of design points extremely high when coupled with other factors' levels.

The strategy behind gridded factorial experiment designs is to specify some low and high values for each factor and a number value for each setting. The simplest of these would be a 2^k gridded factorial, where k is the number of factors, each set at two levels. This method is very efficient for detecting the main effects of an experiment.

If we let a –1 represent the low setting of the factor, and 1 be the high setting of the factor, the number of design points needed for a full factorial experiment will be 2^k, with k again equal to the number of factors.

The benefits of the gridded factorial design, besides the efficiency, are that with the low and high factor settings at –1 and 1, all of the factor vectors are orthogonal and uncorrelated.

If there were a concern about possible quadratic effects in the system, the designer can extend the gridded factorial design and add center points. These center points correspond to factor settings equidistant from the high and low actual factor levels. In the gridded design, the value 0 represents them. With high, center and low factor settings, an experiment designer can explore quadratic effects of a system with 3^k design points in a gridded factorial design.

It is important to note that with the addition of the center point settings and the 0 value representation, the orthogonal and uncorrelated benefits still apply.

I used a 2×3^4 gridded factorial experimental design, augmented by face points and the absolute center point in the four dimensions. I have one binary variable, which causes two separate runs of the experiment at the other four variables' high and low design points. To capture possible quadratic effects, I augmented the experiment design by using three of the four non-binary center (0 setting) points. The fourth factor's levels were set to a level $\sqrt{4}$ times the distance between the center setting and the high and low setting. In four dimensions, this projects a design point through the face of a hypercube to a point with the same leverage as the corner points that will help detect non-linear effects.

This experiment setup will result in 50 design points, as seen in Appendix D. As stated earlier, these design points only include controllable factors; conspicuously absent from the design are many uncontrollable factors that vary through the execution of the simulation. Some examples of these are the number of officers graduated in each branch each fiscal year, the number of officers that suffer attrition and/or recycle during an accession year, or the number of officers that receive an immediate active duty status upon graduation.

These uncontrollable factors cause variability in the system. I would like to explore this variability, and a robust experimental design on the output will help account for it.

D. ROBUST EXPERIMENT DESIGN

From the gridded factorial design, I have 50 design points and a regression model that will allow exploration of the factors' effects on accession training time. However, the manner in which I use the output from these design points can help account for other sources of variability in the system.

A robust experiment design is a powerful tool to help capture the effect of the uncontrollable factors' contribution to variability. Robust design is usually accomplished by crossing the desired design of 50 points with a simple design intended to probe the range of behaviors associated with the uncontrollable factors. This allows the estimation of not only the mean performance at each of the 50 design points, but also the variability of each design point resulting from the uncontrollable factors. Capturing the mean and variance of the simulation's measure of performance at each of the design points and incorporating it into a loss function can provide an idea of how consistent the behavior of the system is in the presence of uncontrollable factors (Sanchez, Sanchez and Ramberg, 1998).

Another benefit to the robust design is that the regression analysis will identify factors that are not significant to the model. With this lack of significance comes flexibility for the decision maker. If a factor associated with a policy or a decision is not significant, then the decision maker can set that factor to any level without repercussions to the outcome. It follows that the decision maker can set these policies that do not have significant effects on the measure of performance to the most cost efficient setting. This provides decision makers with flexibility and a means for identifying ways to conserve resources.

Due to the characteristics of the accession training system and the methods used in coding the simulation, I cannot use the crossed design approach. However, one can estimate the variability in a simulation model by using replication, although doing so is usually less efficient than using a designed experiment.

I will run the simulation 25 times at each design point, generating five fiscal years worth of graduating officers per simulation run. From each run, I will calculate the mean time that all officers spend in accession training. Upon completion of the experiment, I will have 25 mean accession times per design point, on which I can calculate the variance. The result is 25 mean accession training times and their variance at each of the 50 design points. I can conduct two regression analyses on this output. The first regression will be on the 25 mean accession times per design point (1250 data points). The second regression will be on the variance of the mean accession training times at each design point (50 data points).

Once the separate regressions are complete for the estimated mean and variance, I will incorporate the resulting regression equations into a squared error loss function.

The equation below is a mathematical representation of squared error loss:

$$\textbf{Loss} = (p - \tau)^2$$

where **p** is the performance and τ is some desirable target value. It follows:

MRE = Mean Regression Equation
VRE = Variance Regression Equation

$$\textbf{E[Loss]} = (MRE - \tau)^2 + (VRE)$$

To use this loss function in my analysis, I need to determine an appropriate desirable target. A perfect accession training system would have every day charged against the THS account be a training day; this would be the absolute best the Army can achieve. Quantitatively, this corresponds to an accession training system with training times equal to the minimum number of days that an officer would spend training in their courses, in this case, the sum of the number of training days in BOLC plus the number of training days in OBC. This minimum value is different for officers of different branches, due to the fact that the branches' OBC lengths are different.

To calculate a desirable target, I took the ratio of each branch to the total number of accessions in a fiscal year (4500) and multiplied that value by the minimum training time for each branch. The result is a desirable target, τ, that is the expected minimum training time, derived by weighting each branches' minimum training time by the ratio of the officers in that branch to the total accessed for the fiscal year.

Using this method I calculated a desirable target of 117.78 days. In an ideal world, 117.78 days would be the average accession training time with no variance, i.e., a loss function value equal to zero. Although in reality it is impossible to achieve this goal, I will use the results of the regression equations to find and recommend policy settings for the factors that will minimize the loss function relative to the ideal target. Minimizing the loss function will yield BOLC implementation policies that consistently result in low accession times.

Once I have determined the "best" policy settings, I will run the simulation at those policy settings 10 times. By varying the seeds used for random number generation, I will have 10 independent data points on which I can calculate a mean and a variance. I can use the results to confirm the expected performance of the policy recommendation.

E. USE OF RANDOM NUMBERS

Careful use of random numbers is important in simulation and experiment design; proper use of random numbers results in easy replication of the simulation experiment for tighter confidence intervals and the ability to better classify alternative systems or system configurations as “best”, “good” or “inferior”. Smart use of random numbers also allows for better control, or guaranteeing that certain types of bias do not creep into the results. (Law and Kelton, 2000).

The random numbers generated in Java are *pseudo-random numbers*, which means that they are not actually random, but are generated using an algorithm. The algorithm has to start at some point to begin generating numbers; this point is called the *seed*. Using different seeds as start points for random number generators produces different streams of random numbers. However, these streams have a finite cycle length before they start repeating the same sequence of random numbers; the length of this stream depends on the quality of the algorithm behind the random number generator (Law and Kelton, 2000).

The pooled random number generator in Simkit is a high quality number generator, and I used it in my simulation. The pooled generator guarantees that the cycle length of random numbers is the product of the two separate cycle lengths of the two underlying generators, as long as the two cycle lengths are relatively prime. The pooled generator in Simkit has a cycle length of approximately 2^{62}(Bratley, Fox and Schrage, 1987). Simkit’s long cycle length coupled with a simulation design that uses relatively miniscule random number streams insures that cycle length is not an issue for my model.

Furthermore, I am running the simulation 25 times at each design point, and I would like to insure that my use of random numbers does not cause dependency in my model. To insure independence between design points, the simulation randomly assigns seeds for the random number generators in each design point run. This random seed assignment will insure that my use of random numbers does not cause a dependency between the results of design point runs.

One of the goals of this analysis is to determine optimal policy settings for BOLC's implementation that minimize THS account size due to time spent in accession training. Once I have discovered these optimal policies, I would like to compare the validation simulation to the simulation that includes BOLC. Recall that the validation model represents the current accession training system without the implementation of BOLC. Since I will compare two different systems, I will use common random number streams for each of the systems. If the streams were different, then there is the possibility that the different random numbers generated were the cause of any differences in the system. However, if the random number streams are the same for both systems during the execution of the simulation, then it follows that the occurrence of any differences between them result from unequal characteristics within the systems, and not from random number generation.

IV. EXPERIMENT RESULTS AND RESPONSE SURFACE ANALYSIS

A. INITIAL REGRESSION RESULTS

S-PLUS is the software that I used to conduct regression analysis on the experiment output (MathSoft, Inc., 1999). Recall the initial regression model from Chapter 3:

y = Mean(TTT) & Var(TTT)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{15}X_1X_5 + b_{23}X_2X_3 + b_24X_2X_4 + b_{25}X_2X_5 + b_{34}X_3X_4 + b_{35}X_3X_5 + b_{45}X_4X_5 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2$$

Since this is a robust experiment design with the loss function defined in Chapter 3, I must develop a regression equation for the mean and a separate regression equation for the variance.

1. Grand Mean Regression Analysis

Before executing the regression on the grand means, I created some plots of the data to see if I could make any observations that might help my analysis.

The figure below is a plot generated in S-PLUS that creates scatterplots of all variables in a data set versus all others.

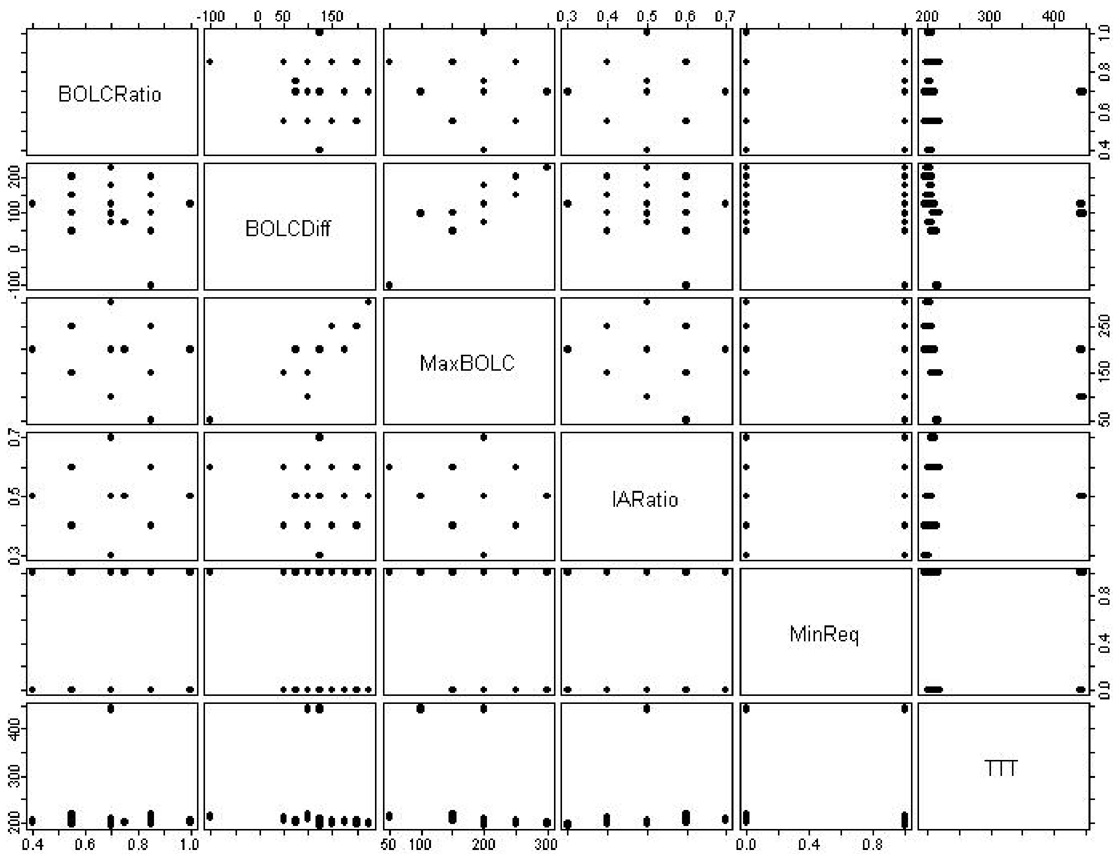


Figure 7. Scatterplots of Variables and Mean Accession Training Time

The individual plots associated with mean accession training time, the response variable TTT, show that there are two design points that returned extremely high accession training times. These outliers correspond to design points 35 and 43, which both have Max BOLC Class Sizes of 100 and Min BOLC Class Sizes of 75. The values returned by these design points are not in the area of interest for my analysis. I am more interested in the policy settings that will return low accession training times. Therefore, removing these two data points from the data set will not have a negative effect on my regression analysis. However, it is important to note that if these variables are set to values in this range, their influence is dominant.

After removing the outlier data points, I created the scatterplots again in the figure below.

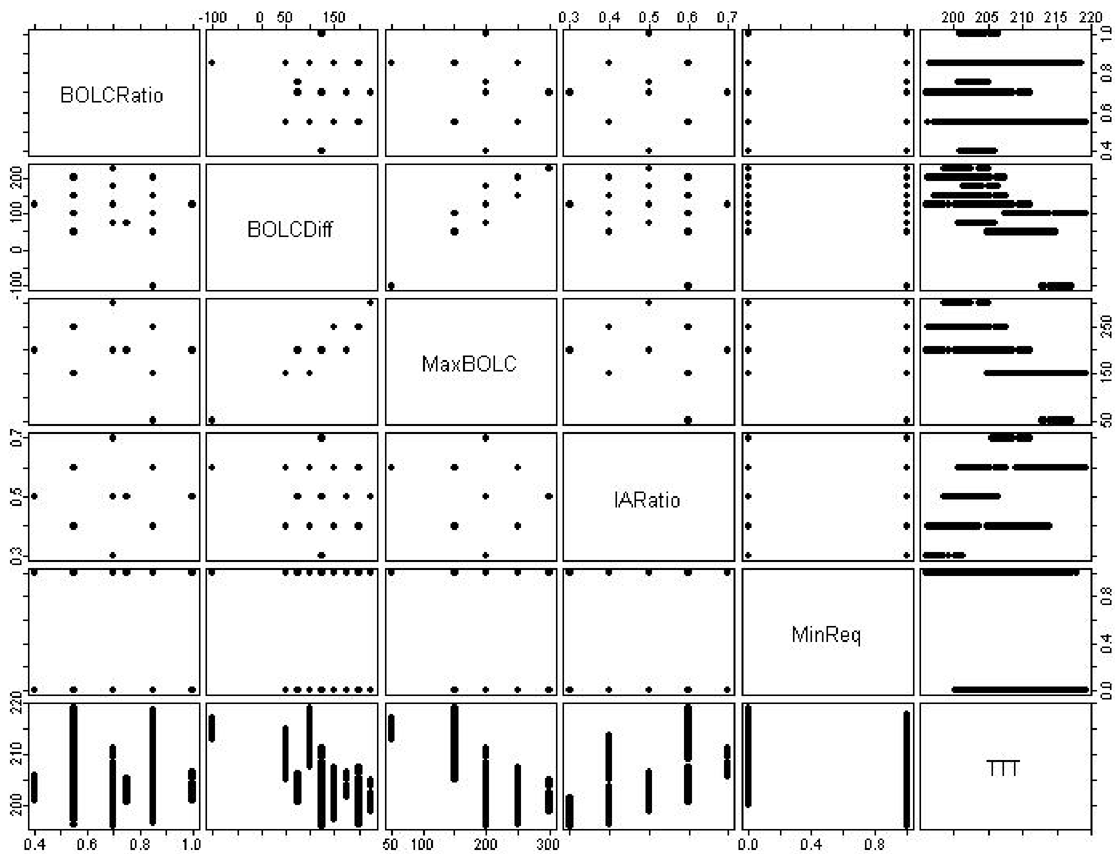


Figure 8. Grand Mean Scatterplots Minus Outliers

With the outliers removed from these plots, S-PLUS automatically changed the scale so that they are readable.

Examining the figure above, the plot between TTT and MaxBOLC and the plot between TTT and BOLCDiff show a possible non-linear relationship, perhaps as high as a cubic relationship. The plot between TTT and IA Ratio shows a relationship that seems linear.

Based on the graphs above, since two of my five factors show possible non-linear behavior, I will add a cubic term for all of my continuous factors in my regression model for the mean. The new regression model with cubic terms is:

y = Mean(TTT)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{15}X_1X_5 + b_{23}X_2X_3 + b_24X_2X_4 + b_{25}X_2X_5 + b_{34}X_3X_4 + b_{35}X_3X_5 + b_{45}X_4X_5 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2 + b_{111}X_1^3 + b_{222}X_2^3 + b_{333}X_3^3 + b_{444}X_4^3$$

With S-Plus and using the new regression model directly above, I conducted a regression analysis on the 25 data points for each of the 48 design points, using the mean as the response variable. The results of this regression are in Appendix E.

As described in Appendix E, the column farthest to the right of the output is the p-values of the terms used in the regression model. I want to improve my response surface model by removing those terms from it that have p-values greater than .05. However, if a main effect has a p-value greater than .05, but is part of an interaction with a p-value less than .05, then I will keep it in the model. In this specific case, the BOLC Branch Ratio and the Min OBC Course Size Requirement factors have p-values greater that .05 associated with its main effect. However, they have interactions with other factors that have p-values lower than .05, which means that they will remain in the model as a main effect despite the high p-value.

The results from the model show that there were a fair number of terms that were significant to the model. Interestingly, the cubic terms for Max BOLC Class Size and Difference Between Max and Min BOLC Class Size were significant. The new regression model with the insignificant terms removed is:

y = Mean(TTT)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{12}X_1X_2 + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{25}X_2X_5 + b_{35}X_3X_5 + b_{22}X_2^2 + b_{33}X_3^2 + b_{222}X_2^3 + b_{333}X_3^3$$

I ran the regression again, using the new model with only the significant terms. The results of this regression are:

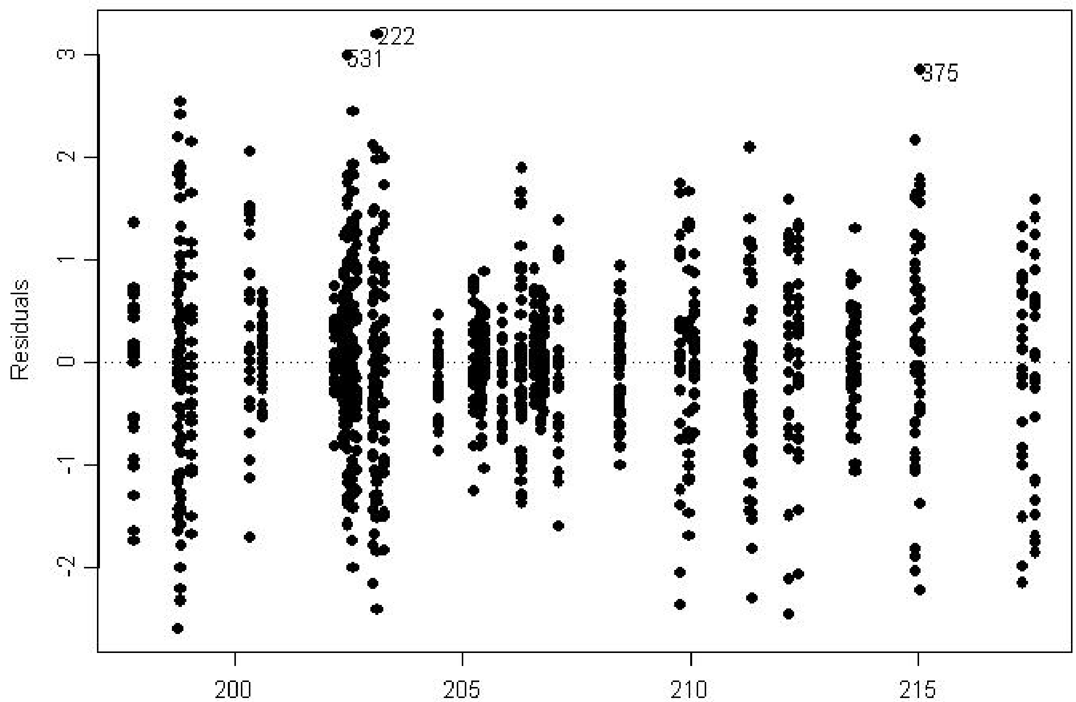
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	354.5147	3.2298	109.7651	0.0000
BOLCRatio	-1.3446	0.7913	-1.6991	0.0896
BOLCDiff	0.4270	0.0095	45.1846	0.0000
MaxBOLC	-2.2355	0.0496	-45.0740	0.0000
IARatio	31.4461	1.1870	26.4910	0.0000
MinReq	-0.8476	0.2643	-3.2066	0.0014
I(BOLCDiff^2)	-0.0021	0.0001	-34.3330	0.0000
I(MaxBOLC^2)	0.0093	0.0002	39.1356	0.0000
I(BOLCDiff^3)	0.0000	0.0000	40.6501	0.0000
I(MaxBOLC^3)	0.0000	0.0000	-32.8202	0.0000
BOLCRatio:MaxBOLC	0.0067	0.0039	1.7510	0.0802
BOLCDiff:MaxBOLC	-0.0009	0.0001	-11.0724	0.0000
BOLCDiff:MinReq	-0.0049	0.0019	-2.5977	0.0095
MaxBOLC:IARatio	-0.0396	0.0058	-6.8605	0.0000
MaxBOLC:MinReq	-0.0073	0.0022	-3.3578	0.0008

Residual standard error: 0.7994 on 1185 degrees of freedom
Multiple R-Squared: 0.9757
F-statistic: 3396 on 14 and 1185 degrees of freedom, the p-value is 0

The figure below shows the predicted values returned by the regression model versus the residuals.

Figure 9. Predicted vs. Residuals in Grand Mean Regression



This graph indicates that the model should be accurate in predicting accession times. The residuals are distributed evenly throughout the graph without any obvious patterns, indicating homoscedasticity.

Placing the coefficients from the regression results above into the regression model returns:

y = Mean(TTT)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = 354.5147 - 1.3446X_1 - 2.2355X_2 + 4270X_3 + 31.4461X_4 - .8476X_5 + .0067X_1X_2 - .0009X_2X_3 - .0396X_2X_4 - .0073X_2X_5 - .0049X_3X_5 + .0093X_2^2 - .0021X_3^2 - .00001198X_2^3 + .000005892X_3^3$$

2. Variance Regression Analysis

Before conducting the variance portion of the regression, I will explore graphs to see if they show anything important. The figure below is the scatterplots of all of the variables versus the variance.

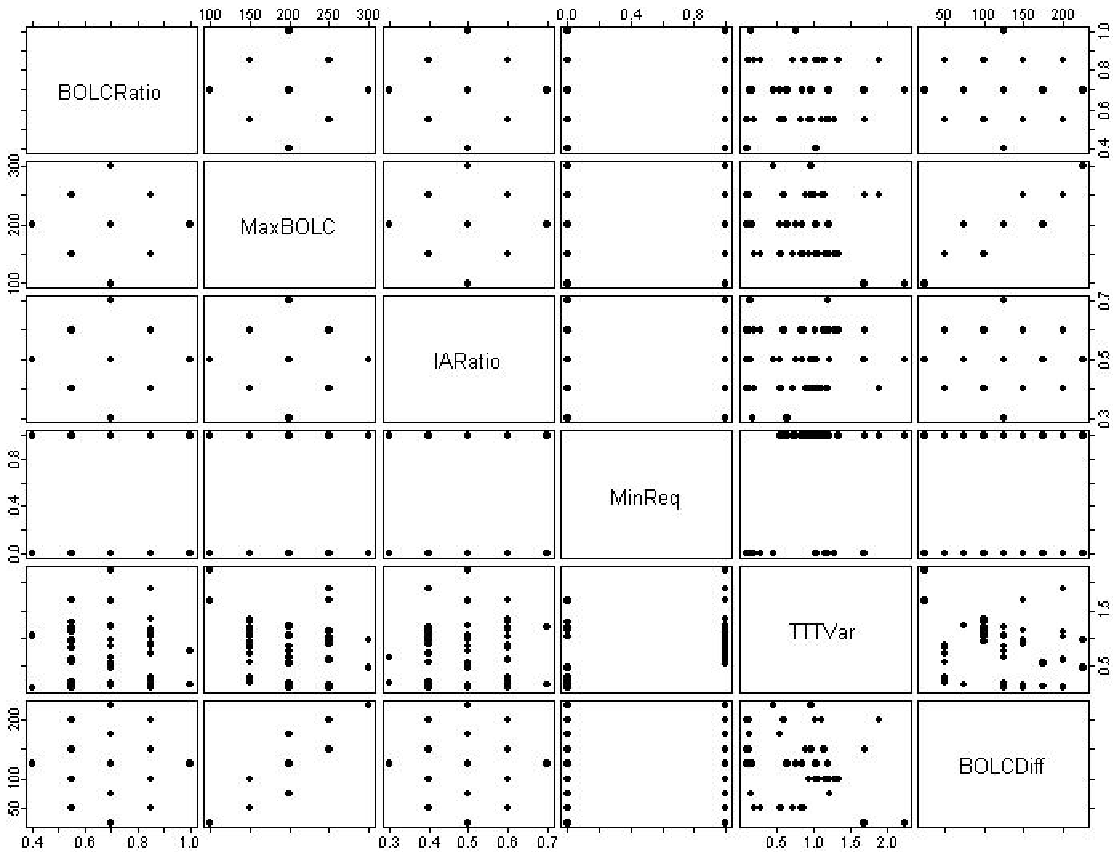


Figure 10. Scatterplots of Variables and Variance

Although these scatterplots do not seem to show any obvious relationships between the variables, I will create a plot of predicted accession time variance versus the residuals using a regression with Max BOLC Class Size as the only predictor variable. The resulting graph is in the figure below.

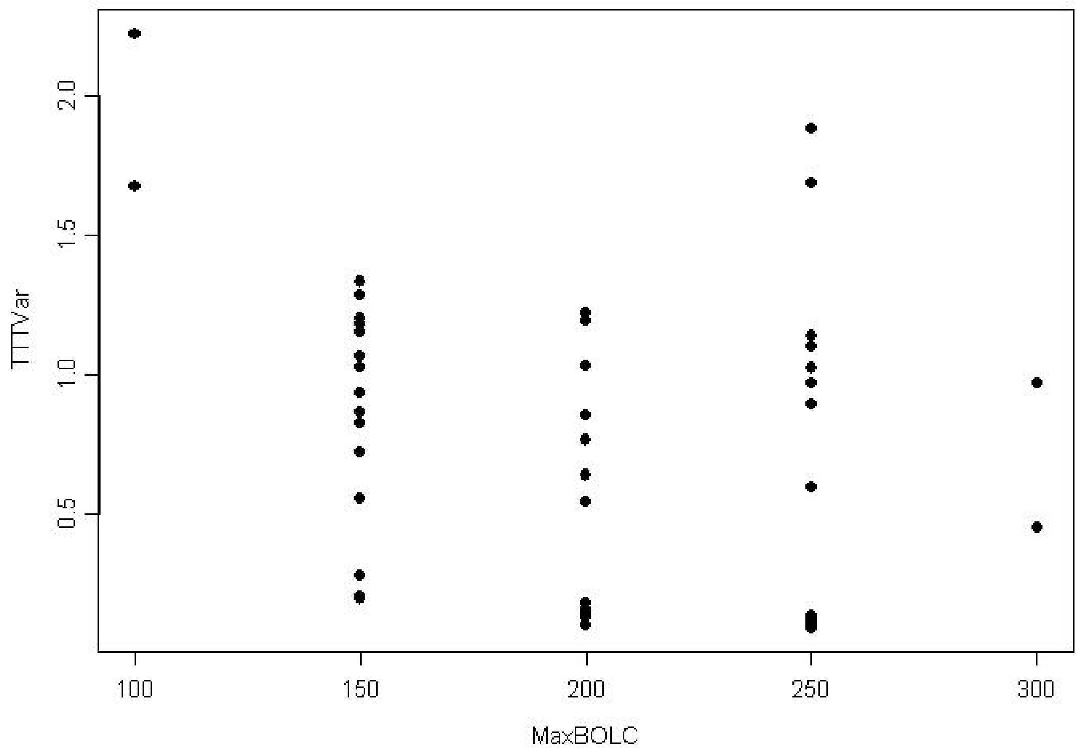


Figure 11. Predicted Variance vs. Residuals Plot with Max BOLC Class Size as the Predictor Variable

This figure indicates possible cubic behavior. To capture that possibility, I will include cubic terms for all factors in the regression model for variance. The new regression model for variance is:

y = Var(TTT)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{15}X_1X_5 + b_{23}X_2X_3 + b_24X_2X_4 + b_{25}X_2X_5 + b_{34}X_3X_4 + b_{35}X_3X_5 + b_{45}X_4X_5 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2 + b_{111}X_1^3 + b_{222}X_2^3 + b_{333}X_3^3 + b_{444}X_4^3$$

Again using S-PLUS, the regression model above, and the design points in Appendix E with the variance of the grand mean results as the response variable, I conducted the regression. The results of this regression are in Appendix F.

Just as in the regression for the grand mean, I want to remove those terms from the model that are not significant. Removing the insignificant terms results in the following model:

y = Var(TTT)

$b_{\#}$ = constants/coefficients

X_1 = BOLC Branch Ratio

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_4 = Immediate Active Duty Ratio

X_5 = Min OBC Course Size Requirement

$$E[y] = b_0 + b_2X_2 + b_3X_3 + b_5X_5 + b_{25}X_2X_5 + b_{22}X_2^2 + b_{33}X_3^2 + b_{222}X_2^3 + b_{333}X_3^3$$

Running the regression again using this new model returned the following results:

```
Coefficients:
                    Value Std. Error  t value Pr(>|t|)
   (Intercept)  17.7080   2.7538     6.4304   0.0000
       MaxBOLC  -0.2875   0.0537    -5.3564   0.0000
      BOLCDiff   0.0916   0.0228     4.0245   0.0002
        MinReq  -0.3915   0.2998    -1.3056   0.1990
  I(MaxBOLC^2)   0.0013   0.0003     4.6927   0.0000
 I(BOLCDiff^2)  -0.0007   0.0002    -3.5506   0.0010
  I(MaxBOLC^3)   0.0000   0.0000    -4.2001   0.0001
 I(BOLCDiff^3)   0.0000   0.0000     3.2569   0.0023
MaxBOLC:MinReq   0.0053   0.0015     3.6350   0.0008

Residual standard error: 0.2522 on 41 degrees of freedom
Multiple R-Squared: 0.8227
F-statistic: 23.78 on 8 and 41 degrees of freedom, the p-value is 4.311e-013
```

This model returns a high R-Squared and the predicted variance versus residuals in the figure below:

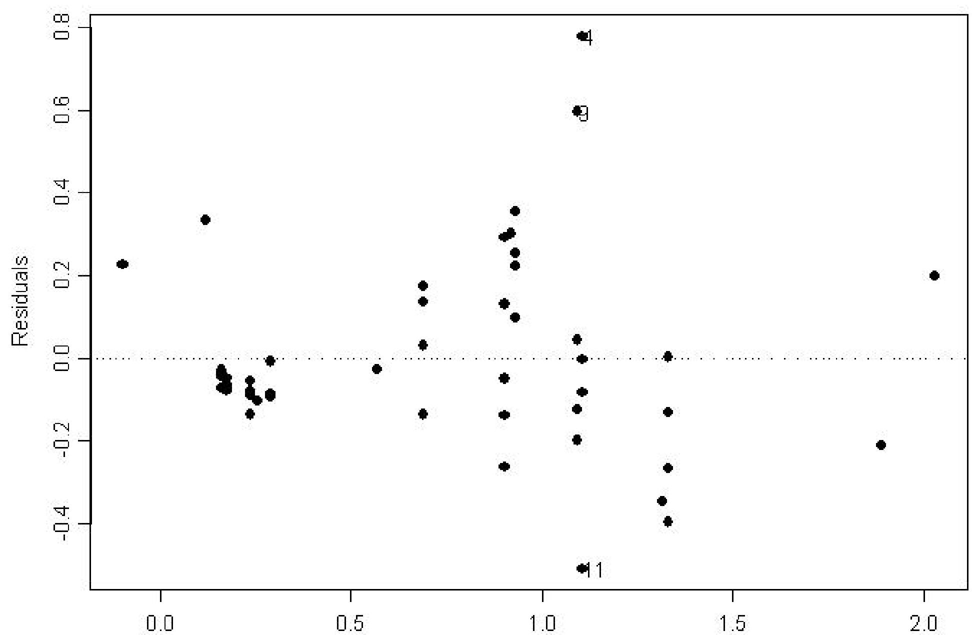


Figure 12. Predicted vs. Residuals in Variance Regression

The figure above shows some heteroscedastic behavior which results in poor predictions by the regression equations. In an attempt to remove the heteroscedasticity, I conducted a transformation on the regression model by making the natural log of the variance the response variable. The regression model with the tranformation is as follows:

y = Variance

$b_{\#}$ = constants/coefficients

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_5 = Min OBC Course Size Requirement

$$\ln(E[y]) = b_0 + b_2X_2 + b_3X_3 + b_5X_5 + b_{25}X_2X_5 + b_{22}X_2^2 + b_{33}X_3^2 + b_{222}X_2^3 + b_{333}X_3^3$$

Executing a regression on this transformed model yields the following results:

```
Coefficients:
                  Value Std. Error  t value Pr(>|t|)
   (Intercept)  17.7527   4.2778     4.1499   0.0002
       MaxBOLC  -0.3126   0.0834    -3.7491   0.0005
      BOLCDiff   0.1380   0.0354     3.9020   0.0003
        MinReq  -0.9376   0.4658    -2.0130   0.0507
  I(MaxBOLC^2)   0.0013   0.0004     3.0377   0.0041
 I(BOLCDiff^2)  -0.0011   0.0003    -3.3979   0.0015
  I(MaxBOLC^3)   0.0000   0.0000    -2.5453   0.0148
 I(BOLCDiff^3)   0.0000   0.0000     3.0827   0.0037
MaxBOLC:MinReq   0.0120   0.0023     5.3088   0.0000

Residual standard error: 0.3918 on 41 degrees of freedom
Multiple R-Squared: 0.8763
F-statistic: 36.29 on 8 and 41 degrees of freedom, the p-value is 3.331e-016
```

The residual plot in the figure below shows a slight improvement over the previous model.

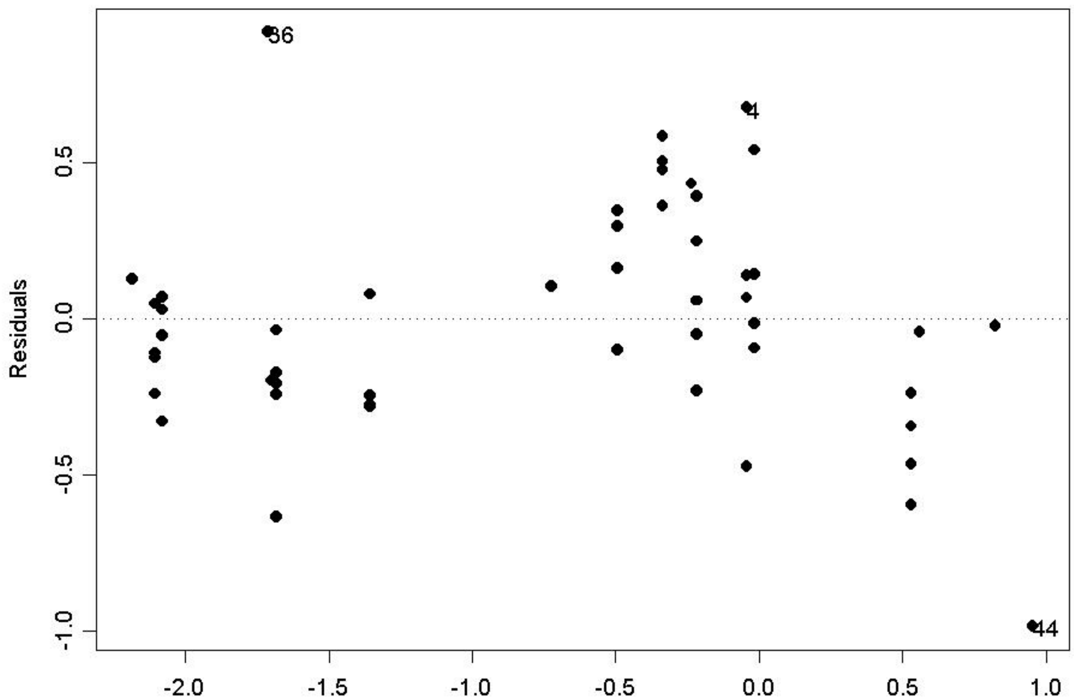


Figure 13. Predicted vs. Residuals in Transformed Variance

I have tried various transformations on this model to try to reduce heteroscedasticity, and none of them returned an adequate fit against the residuals. I decided to keep the model with the log transformation, because regression is a very robust operation. Even though this variance model is returning residuals that are not homoscedsastic, I still can use it in the loss function to help predict policy settings that minimize accession training time.

Using the coefficients from the natural log transform regression for the variance regression model returns the following regression equation:

y = Variance

$b_{\#}$ = constants/coefficients

X_2 = Max BOLC Class Size

X_3 = Difference Between Max and Min BOLC Class Size

X_5 = Min OBC Course Size Requirement

$$E[\ln(y)] = 17.7527 - .3126X_2 + .1380X_3 - .9376X_5 + .0120X_2X_5 + .0013X_2^2 - .0011X_3^2 - .000001821X_2^3 + .000002629X_3^3$$

B. RESPONSE SURFACE ANALYSIS

The loss function provides some insight into the different controllable factors and how they effect the accession training time for officers. Recall the general form of the loss function:

MRE = Grand Mean Regression Equation

VRE = Variance Regression Equation

$$\mathbf{E[Loss]} = (MRE - \tau)^2 + (VRE)$$

At this point in the loss function analysis, I need to properly scale the VRE so that it reflects the variance of one officer through the system. Currently, it reflects the variance of the mean accession time for all officers. Multiplying the VRE by the number of observations for each simulation run (22,500) will return a VRE with the appropriate scale. Recalling that the desirable target calculated earlier is equal to 117.78 days, the loss function becomes:

$$\textbf{E[Loss]} = (MRE - 117.78)^2 + 22500(VRE)$$

Using the equations from the results of the regression analyses above result in the following loss function:

$b_\#$ = constants/coefficients
X_1 = BOLC Branch Ratio
X_2 = Max BOLC Class Size
X_3 = Difference Between Max and Min BOLC Class Size
X_4 = Immediate Active Duty Ratio
X_5 = Min OBC Course Size Requirement

$$\textbf{E[Loss]} = ((354.5147 - 1.3446X_1 - 2.2355X_2 + 4270X_3 + 31.4461X_4 - .8476X_5 + .0067X_1X_2 - .0009X_2X_3 - .0396X_2X_4 - .0073X_2X_5 - .0049X_3X_5 + .0093X_2^2 - .0021X_3^2 - .00001198X_2^3 + .000005892X_3^3) - 117.78)^2 + 22500(e^{(17.7527 - .3126X2 + .1380X3 - .9376X5 + .0120X2X5 + .0013X22 - .0011X32 - .000001821X23 + .000002629X33)})$$

The following sections describe how the five different factors in the regression model influence the accession training time.

1. BOLC Branch Ratio

The BOLC Branch Ratio factor has almost no significance to the loss function. The only reason that it remained in this loss function analysis is that it has a significant interaction with the Max BOLC Class Size factor. The reason for the BOLC Branch Ratio factor has almost no significance is due in part to the flexibility of having three different installation hosting BOLC.

If an officer from a particular branch cannot attend a BOLC because his or her addition to the course will violate the branch ratio there, an opportunity exists to attend an alternate BOLC at a different installation that more than likely starts approximately one week later. In the rare instance that the second BOLC has the ratio constraint problem, a third installation hosting a BOLC will follow shortly after the second attempted attendance.

In essence, the flexibility three different BOLC installations provide to the accession training system negate the problems the branch ratio constraint might cause.

2. Min OBC Course Size Requirement

As in the BOLC Branch Ratio factor above, the Min OBC Course Size Requirement shows very little significance in the model. This factor is not significant alone, but has important interactions that have an impact on the accession training time.

3. Max BOLC Class Size, Min BOLC Class Size, and Immediate Active Duty Ratio

These three factors were very significant to the two regression analyses, and therefore are significant to the loss function. I would like to determine level settings for all of the factors that minimize the loss function; minimizing the loss function will in turn minimize the time spent in the THS account.

Recall the loss function derived from the regression analysis in Section A of this chapter:

$b_{\#}$ = constants/coefficients
X_1 = BOLC Branch Ratio
X_2 = Max BOLC Class Size
X_3 = Difference Between Max and Min BOLC Class Size
X_4 = Immediate Active Duty Ratio
X_5 = Min OBC Course Size Requirement

$$\mathbf{E[Loss]} = ((354.5147 - 1.3446X_1 - 2.2355X_2 + 4270X_3 + 31.4461X_4 - .8476X_5 + .0067X_1X_2 - .0009X_2X_3 - .0396X_2X_4 - .0073X_2X_5 - .0049X_3X_5 + .0093X_2^2 - .0021X_3^2 - .00001198X_2^3 + .000005892X_3^3) - 117.78)^2 + 22500(e^{(17.7527\ -\ .3126X2\ +\ .1380X3\ -\ .9376X5\ +\ .0120X2X5\ +\ .0013X22\ -\ .0011X32\ -\ .000001821X23\ +\ .000002629X33)})$$

Using the loss function as an objective function, I formulated a simple optimization problem that would determine the optimal settings for the four factors. The complete formulation is in Appendix G.

After implementing the formulation in Microsoft EXCEL Solver, the following factor settings minimized the loss function:

BOLC Branch Ratio = .55
Max BOLC Class Size = 250
Difference Between Max/Min BOLC Class Size = 179.44
Min OBC Course Size Requirement = Not Required
Immediate Active Duty Ratio = 0.4

The predicted loss at this optimal solution is 8012.58 days^2, with mean portion of the loss function predicting a mean accession time of 201.17 days and a variance prediction of .04700 days^2 without scaling.

I built a graph to insure that this optimal solution returned a global minimum for the loss function. Since there are three continuous variables, I varied the loss function value at each of these variables, while holding the others constant at the optimal settings. I will examine the graph to see if there is more than one stationary point in any dimension for which the EXCEL Solver might have returned an optimal policy solution.

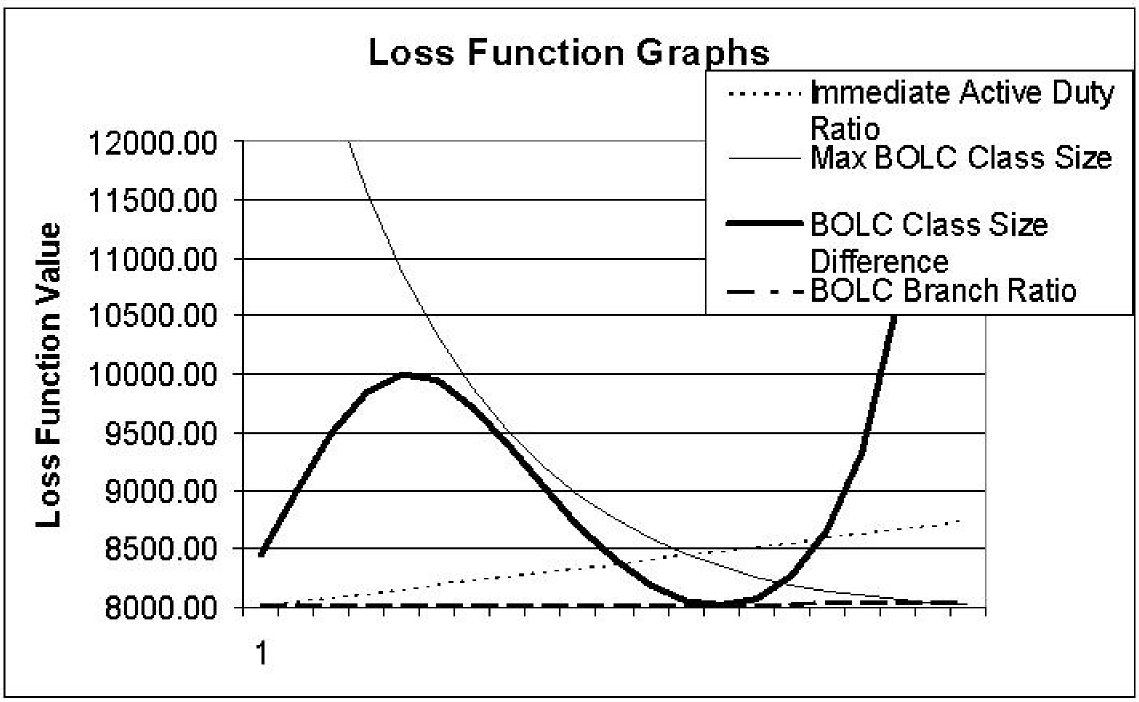


Figure 14. Graph of Loss Function

As seen in the figure above, over the interval defined by the highest and lowest settings for each of the continuous variables, there is only one stationary point corresponding to a minimization of the loss function. Interestingly, the loss function values when varying the Difference Between the Max and Min BOLC Class Size show two stationary points in the interval I am exploring.

Running the simulation ten times at these policy settings:

- BOLC Branch Ratio -- .55 (optimal setting)
- Min BOLC Class Size –– 71 (closest integer number to optimal setting)
- Max BOLC Class Size –– 250 (optimal setting)
- Immediate Active Duty Ratio –– 0.4 (optimal setting)
- Min OBC Course Size Requirement –– Not Required (optimal setting)

yielded the following results:

Table 3. Results of Simulation at Optimal Policy Settings

Run	***Mean Accession Time (Days)***
1	202.20
2	202.15
3	202.63
4	201.98
5	201.85
6	202.67
7	202.31
8	202.29

9	202.69
10	202.27

The grand mean for this data is 202.30 days with a variance of .0864 $days^2$. Scaling the variance appropriately results in a new variance measure of 1943.90 $days^2$. Recall the general form of the loss function:

E[Loss] = $(MRE-117.78)^2 + 22500(VRE)$

Incorporating the grand mean above into the MRE portion of the loss function and the variance into the VRE part returns a value of 9087.87 $days^2$. The predicted loss function value at these policy settings was 8012.02 $days^2$. Simulation runs at the optimal policy settings returned accession training times close to the values predicted by the regression equations incorporated into the loss function.

Recall from the regression outputs that the residual standard error from the mean regression was .7994 and the residual standard error from the variance regression was .3918 without scaling. Therefore, 95% confidence intervals for the predicted mean and variance of accession training time at the optimal settings are:

Mean –- 201.17 $\pm$ 1.5668 days

Variance -- .047000 $\pm$ .7679 $days^2$

The grand mean and the variance without scaling of the simulation run at the optimal policy settings were 202.30 days and .0864 days^2 respectively. Therefore, the simulation returned values for mean and variance of accession training time that were within the confidence intervals calculated above.

Using the grand mean and variance from the simulation runs at each design point as input into the above loss function returns the following graph.

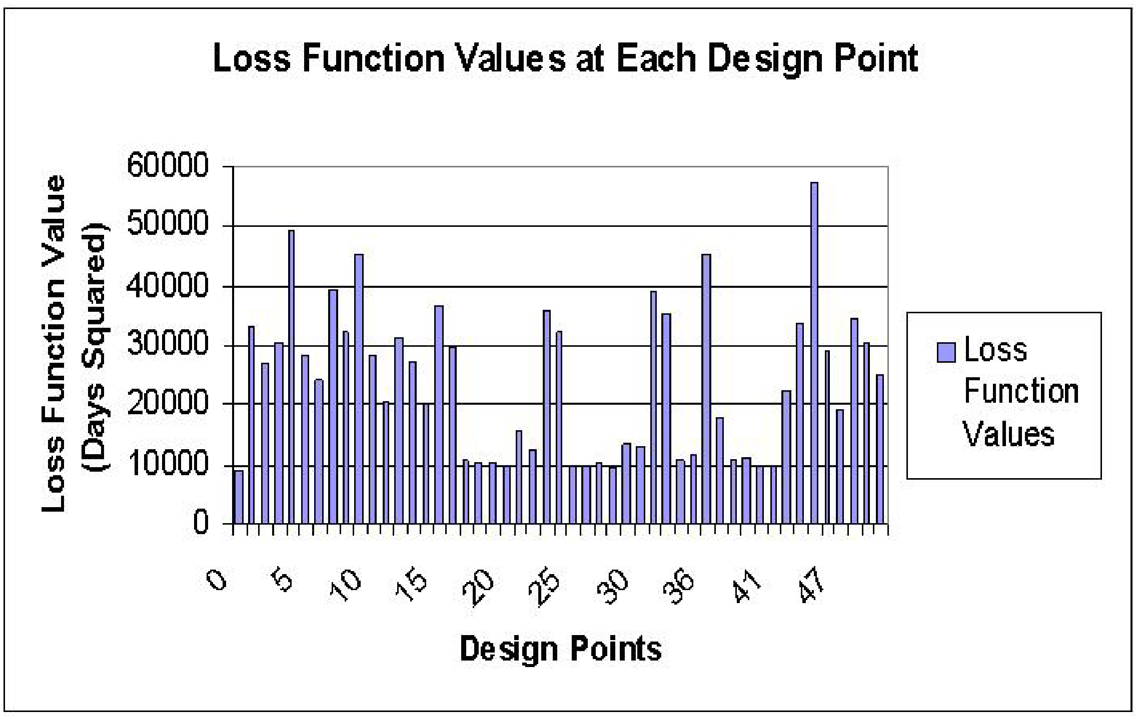


Figure 15. Loss Function Values at Each Design Point

The design points on the extreme left of the graph above is the result from the optimal setting, 9087.87 days^2. It is indeed an optimal setting when comparing its loss function value with the other design points. Other design points and their settings that were close to the optimal are in the table below.

Table 4. Design Points with Low Loss Function Values

Design Point	*BOLCRatio*	*MaxBOLC*	*IARatio*	*MinReq*	*BOLCDiff*	*Var(TTT)*	*Mean(TTT)*	*Loss Function Value*
Optimal	*0.55*	*250*	*0.4*	*0*	*172*	*1943.90*	*202.3*	*9087.87*
28	0.55	250	0.4	0	200	2151.00	202.41	9313.2369
26	0.55	250	0.4	0	150	2664.00	202.34	9814.3936
25	0.55	250	0.6	0	150	2022.53	206.51	9893.5129
41	0.7	200	0.3	1	125	3523.50	197.76	9920.3004
40	1	200	0.5	0	125	2225.25	205.64	9944.6296

The first row of the table above is the loss function value at the optimal policy settings. Design point 28 returns a loss function value of 9313.24 days^2. Comparing the policy settings from design point 28 with the optimal settings, we find that the only difference is the setting of the Difference Between the Max and Min BOLC Class Size factor. Note that design point 41 returns the minimum mean, but is not recommended due to its high variability.

C. RUNNING BASELINE SIMULATION AT OPTIMAL POLICY SETTINGS

Recall from Chapter 2 that I developed a separate simulation that emulated the accession training system without the implementation of BOLC. The input parameters for the validation were not optimized. I set the parameters to levels accurate in regard to the current accession training system.

Since I would like to determine the effect that implementation of BOLC will have on the accession training system, and ultimately the THS account, I must find a way to compare the baseline simulation results with the results of the optimal simulation runs with BOLC. Any comparisons between the two models as they stand now would not be valid, as the BOLC model has been optimized and the baseline model has not.

Therefore, to make a valid comparison, I will run the baseline model at the policy settings derived from the optimization of the regression analyses on the output from the simulation with BOLC implemented. Running the two at the same policy same settings should provide a picture of the impact that BOLC will have on the accession training system.

The table below shows the results of the running the baseline simulation at the BOLC optimal policy settings.

Table 5. Baseline Model Run at Optimal BOLC Policy Settings

Branch	***Baseline Mean***	***Baseline Std Dev***	***Optimal Mean***	***Optimal Std Dev***	***Difference***
TOTAL	*186.02*	*39.93*	*179.1*	*37.36*	*6.92*
Adjutant General	174.88	36.02	170.73	37.55	4.15
Finance	164.07	49.11	155.34	47.62	8.73
Infantry	183.04	34.76	177.79	35.61	5.25
Field Artillery	214.77	38.60	208.64	38.35	6.13
Armor	184.12	46.70	178.45	44.42	5.67
Air Defense	204.5	47.58	200.61	48.51	3.89
Aviation	230.01	53.40	223.44	55.22	6.57
Engineer	172.93	40.84	166.99	39.67	5.94
Military Police	166.67	39.32	160.73	39.89	5.94
Chemical	207.1	42.17	200.65	40.01	6.45
Military Intelligence	185.28	28.56	178.43	31.06	6.85
Signal Corps	172.59	26.99	158.43	27.24	14.16
Ordnance	191.24	38.77	182.47	38.72	8.77
Transportation	171.28	41.89	165.38	40.35	5.9
Quartermaster	167.8	33.23	158.38	34.29	9.42

This table shows that applying the optimal policy settings from the system with BOLC results in a decrease of approximately seven accession training days per officer. All branches improved their average training time, with Signal Corps showing the greatest improvement and Adjutant General the least.

Recall the mean accession training time returned from the simulation at the optimal policy settings is 202.30 days. Running the baseline model at the optimal policy settings returns a mean accession time for all officers of 179.10 days. Comparing the output from the two different models shows that adding BOLC to my simulated accession training system increased accession training time by approximately 23 days per officer.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Of the policies TRADOC has yet to publish, their decisions in regard to the maximum and minimum class sizes for a BOLC will have the greatest impact on the THS account.

The model developed in this simulation is very sensitive to the immediate active duty ratio. The immediate active duty level should be set as low as feasibly possible.

The BOLC branch ratio and the minimum OBC class size requirement are significant only in their interactions with other factors; alone they are not as important to the accession training system.

When comparing the simulation output from the system without BOLC to the system with it, I found that implementing the new accession system added just over 23 days of accession training time per officer to the simulated accession training system. It is important to note that this increase is based on a BOLC schedule that is uniformly distributed throughout the training year. It is possible that optimizing a schedule for the implementation of BOLC could create a significant decrease in the number of accession training days.

B. RECOMMENDATIONS

I recommend that the Military Forecasting and Strength Analysis Division, in their analysis and in their BOLC planning and organization conferences with TRADOC, stress the importance of the maximum and minimum BOLC class sizes. As analysts from TRADOC and Army G-1 explore policies regarding BOLC, they should give these policies extra consideration. Currently, TRADOC plans on class sizes of 200; if training facilities permit, increasing class capacity as much as possible while keeping the minimum class quota for a BOLC to start would positively affect the THS account.

I further recommend that before the implementation of BOLC, analysts optimize its schedule so that its impact on accession training time is minimal. An optimized schedule would handle the summer surge and the low traffic times better than the uniform schedule used in this model.

C. FURTHER RESEARCH

I have divided this section into three distinct subjects. In the first, I describe specific additions to the simulation that would more accurately represent the accession training system. In the next section, I discuss the transition of this problem from one of accession training time to an analysis of the cost versus the benefit of implementing optimal policies. Finally, I discuss changes to the analysis of this thesis that I would have liked to have implemented had time permitted.

1. Improving the Simulation

One significant area left for exploration in this problem is the addition of training areas to the simulation. As described in Chapter 2, all accession training events are not equal. To simplify my model, I aggregated many of the possible training schools into the **Thirty Day Training()** event. This event simulated officers going to Airborne, Air Assault School and other courses. This is somewhat unrealistic, as these different schools have different recycle rates, different attrition rates, have varying travel times between their course and others, and have variable course lengths.

I have designed the simulation code so that analysts can easily incorporate additional modules into the model. For example, one could easily incorporate a module for Ranger School. This training is important because a significant portion of combat arms officers attend the course prior to their arrival to their first operational assignment. Ranger School is a long, demanding course with high attrition and recycle rates. Explicitly including this course into the model would provide a more accurate picture of accession training time.

Other modules that would help provide a more accurate reflection of accession training time are Airborne School and Air Assault School. Like Ranger School, a significant portion of officers from all branches attends these two schools. However, they are located at two different installations and have separate and distinct course sizes, recycle and attrition rates and course lengths. Conducting the appropriate research and incorporating a module for each of these schools individually would improve the model.

2. Cost Analysis

Another important area of research would be in the area of cost analysis. This thesis has explored how different policy decisions affect the THS account. Extensions to this research would include comparisons of how many accession days a policy decision might save versus the cost of implementing the policy. Included in this analysis would be a study of the cost to the Army of having a 2LT in the accession training system for a single day. The product of this cost and the total number of man-days saved by a policy setting results in a measure of budget savings for the Army. Comparing this savings with the cost of implementing the policy is a natural extension of this problem.

3. Changes to Current Analysis

As I progressed through this problem, my analysis led me in some unexpected directions. Results from the simulation and from the response surface analysis pointed my efforts in other obvious directions that I wish I had time to pursue.

The first of these areas would be a comparison by the different branches of the Army of the accession training time between the model with BOLC and without it. Recall that these are two separate simulations with different code. To streamline the simulation with BOLC, I removed the capability to easily distinguish between officers of different branches as they report their time spent in the accession training system. With additional time, I could return to the code and provide the capability to gather training time statistics based on branch. This additional information could also provide insight into how the branches with a large number of officers per fiscal year effect the training system with BOLC.

As I completed my response surface analysis, I found that a better response variable for my regression analysis would have been Days in Excess of Actual Training. This would include days spent in graduation delay, snowbird and travel time. This change would have made my loss function easier to understand:

MDEATRE = Mean Days in Excess of Actual Training Regression Equation

VDEATRE = Variance of Days in Excess of Actual Training Regression Equation

$$\mathbf{E[Loss]} = (\text{MDEATRE} - \tau)^2 + 22500(\text{VDEATRE})$$

The desirable target, τ, in this case would be zero, as we would want no days of excess training.

Changing the simulation code to capture this different response variable is a significant manipulation of the model. In the long run, the analysis might have been more descriptive of the cost to the THS account. However, changing the program to incorporate this change was not feasible in the time frame allotted to the thesis.

The final improvement to my analysis I alluded to in the text in Chapter 3. I decided to use a robust experiment design to capture the variance caused by uncontrollable variables in the system. However, when gathering parameter data about the Army's accession training system, I did not anticipate the use of a robust design. The robust design requires changing the input parameters of the uncontrollable variables to capture their effects on the variance of the response variable.

Since I did not anticipate using a robust design when I wrote the simulation code, I failed to design flexibility for the uncontrollable factors into the simulation. Using replication made the robust analysis possible. However, had I made the code more flexible, I would have been able to specifically identify the degree to which each of the uncontrollable factors in the system affected the variance of the accession training time.

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APPENDIX A. ACCESSION INPUT DATA

This appendix contains tables that hold the input parameters used during the accession portion of the simulation.

WEST POINT INPUT DATA

Table 6. West Point Branch Graduation Rates

Branch	***Min Rate***	***Avg Rate***	***Max Rate***
Infantry	.190	.220	.250
Armor	.128	.158	.188
Field Artillery	.169	.199	.229
Air Defense	.036	.066	.096
Aviation	.096	.126	.156
Engineer	.068	.098	.128
Signal Corps	.020	.035	.050
Military Police	.010	.020	.030
Military Intelligence	.010	.025	.040
Chemical	.001	.003	.005
Adjutant General	.004	.007	.010
Finance	.001	.002	.003
Ordnance	.005	.011	.017
Transportation	.010	.017	.024
Quartermaster	.007	.012	.017

Table 7. West Point Graduation Dates and Class Size

Date	***Class Size***
22 December	17
2 June	906
27 June	13

Table 8. Ratios of Graduation Delay for West Point Graduating Classes

Delay Category	***Min Ratio***	***Avg Ratio***	***Max Ratio***
Fifteen Days	.0946	.1067	.1188
Forty-five Days	.3256	.3432	.3608
Seventy-five Days	.4983	.5204	.5423
Half-year Delay	.0220	.0297	.0374

ROTC INPUT DATA

Table 9. ROTC Branch Graduation Rates

Branch	***Min Rate***	***Avg Rate***	***Max Rate***
Infantry	.125	.158	.188
Armor	.055	.086	.116
Field Artillery	.126	.156	.186
Air Defense	.014	.044	.074
Aviation	.049	.079	.109
Engineer	.048	.078	.108
Signal Corps	.044	.074	.104
Military Police	.016	.031	.046
Military Intelligence	.027	.057	.087
Chemical	.025	.055	.085
Adjutant General	.006	.012	.018
Finance	.001	.002	.003
Ordnance	.043	.073	.103
Transportation	.018	.048	.078
Quartermaster	.017	.047	.077

Table 10. Ratio of ROTC Graduates Categorized Immediate Active Duty

Ratio of Immediate Active Duty	***Ratio for Regular Active Duty***
.48	.52

Table 11. ROTC Graduation Dates and Graduating Class Size

Dates	***Class Size***
22 November	128
6 December	128
13 December	128
20 December	128
11 January	128
1 May	128
8 May	128
15 May	128
22 May	257
1 June	386
8 June	257
15 June	128
22 June	128
29 June	128
28 July	128
15 August	128

Table 12. ROTC Graduation Delay Data (Days)

Min Delay	***Avg Delay***	***Max Delay***
15	30	45

OCS INPUT DATA

Table 13. OCS Branch Graduation Rates

Branch	***Min Rate***	***Avg Rate***	***Max Rate***
Infantry	.193	.223	.253
Armor	.093	.123	.153
Field Artillery	.071	.101	.131
Air Defense	.080	.110	.140
Aviation	.010	.020	.030
Engineer	.033	.063	.093
Signal Corps	.046	.076	.106
Military Police	.012	.042	.072
Military Intelligence	.015	.033	.051
Chemical	.057	.087	.117
Adjutant General	.005	.011	.017
Finance	.001	.003	.005
Ordnance	.015	.039	.053
Transportation	.013	.043	.073
Quartermaster	.015	.026	.037

Table 14. OCS Graduation Delay Data (Days)

Min Delay	***Avg Delay***	***Max Delay***
7	14	30

Table 15. OCS Graduation Dates and Graduating Class Size

Dates	***Class Size***
22 November	138
14 December	131
25 January	129
14 April	152
10 May	145
7 June	143
16 August	162

APPENDIX B. BOLC INPUT DATA

The appendix consists of tables that hold the input data used for the BOLC portion of the simulation.

Table 16. General BOLC Input Data

BOLC Course Length	35 Days
BOLC Min Class Size	100
BOLC Max Class Size	150

Table 17. BOLC Attrition and Recycle Rates

	Attrition			**Recycle**		
	Min	*Avg*	*Max*	*Min*	*Avg*	*Max*
Rates	.0000	.0016	.0032	.0000	.0050	.0064

Table 18. BOLC Scheduled Start Dates by Installation

Benning	***Sill***	***Bliss***
27 December	5 January	23 January
23 February	2 March	9 March
16 March	23 March	10 April
1 May	14 May	31 May
11 June	18 June	25 June
2 July	9 July	16 July
23 July	30 July	6 August
13 August	20 August	20 August
20 August	27 August	3 September
10 September	17 September	24 September
1 October	8 October	15 October
22 October	8 November	

APPENDIX C. OBC INPUT DATA

Appendix C consists of tables that hold the input data for the OBC portion of the simulation.

Table 19. OBC Travel Data

		Travel Days to…		
Branch	**OBC Loc**	**Ft. Benning**	**Ft. Sill**	**Ft. Bliss**
Infantry	Benning	0	3	4
Field Artillery	Sill	3	0	2
Armor	Knox	2	3	4
Aviation	Rucker	1	3	4
Engineers	Wood	3	2	3
Air Defense	Bliss	4	2	0
Adjutant General	Jackson	1	3	5
Finance	Jackson	1	3	5
Signal Corps	Gordon	1	3	5
Military Police	Wood	3	2	3
Chemical	Wood	3	2	3
Military Intelligence	Huachuca	5	3	1
Ordnance	Aberdeen	3	4	6
Quartermaster	Lee	2	4	6
Transportation	Eustis	2	4	6

Table 20. OBC Attrition and Recycle Rates by Branch

	Attrition Rates			*Recycle Rates*		
Branch	***Min***	***Avg***	***Max***	***Min***	***Avg***	***Max***
Infantry	.0000	.0031	.0063	.0000	.0094	.0125
Air Defense	.0000	.0056	.0119	.0000	.0056	.0119
Adjutant General	.0000	.0000	.0143	.0000	.0000	.0143
Armor	.0000	.0000	.0108	.0000	.0216	.0431
Aviation	.0000	.0395	.0988	.0000	.0395	.0790
Chemical	.0000	.0000	.0137	.0000	.0000	.0068
Engineer	.0000	.0000	.0535	.0000	.0000	.0340
Field Artillery	.0000	.0140	.0280	.0000	.0280	.0630
Finance	.0000	.0000	.0545	.0000	.0000	.0180
Military Intelligence	.0000	.0000	.0317	.0000	.0159	.0370
Military Police	.0000	.0167	.0333	.0000	.0027	.0476
Ordnance	.0000	.0000	.0196	.0000	.0000	.0392
Quartermaster	.0000	.0000	.0095	.0000	.0000	.0286
Signal Corps	.0000	.0067	.0200	.0000	.0020	.0040
Transportation	.0000	.0000	.0032	.0000	.0000	.0026

Table 21. OBC Course Length, Minimum and Maximum Sizes

Branch	**Length(Days)**	**Min Size**	**Max Size**
Infantry	68	48	103
Field Artillery	96	67	113
Armor	75	21	58
Aviation	110	1	35
Engineers	89	25	61
Air Defense	96	48	103
Adjutant General	54	5	39
Finance	61	4	22
Signal Corps	82	41	78
Military Police	82	15	44
Chemical	89	27	42
Military Intelligence	82	15	44
Ordnance	82	16	30
Quartermaster	54	24	47
Transportation	75	25	40

Table 22. Air Defense OBC Schedule

10 April	15 July	15 August	15 September	15 October

Table 23. Adjutant General OBC Schedule

3 March	30 June	4 August	4 November

Table 24. Armor OBC Schedule

22 January	29 March	22 April	29 June	15 July
5 August	30 August	24 September	19 October	18 November

Table 25. Aviation OBC Schedule

3 October	18 October	1 November	18 November	3 December
17 December	14 January	29 January	12 February	27 February
14 March	28 March	9 May	23 May	9 June
23 June	8 July	22 July	5 August	18 August
3 September	17 September			

Table 26. Chemical OBC Schedule

3 January	15 March	31 May	15 June
2 August	25 August	14 September	31 October

Table 27. Engineer OBC Schedule

3 January	27 March	24 April	31 May	12 July
2 August	28 August	14 September	11 October	15 November

Table 28. Field Artillery OBC Schedule

6 January	24 March	20 May	3 July
10 August	8 September	11 October	

Table 29. Finance OBC Schedule

4 March	1 August	15 November

Table 30. Infantry OBC Schedule

14 January	24 April	15 July
2 August	7 September	18 October

Table 31. Military Intelligence OBC Schedule

4 December	8 March	5 April	10 May	7 June
4 July	3 August	8 September	12 October	15 November

Table 32. Military Police OBC Schedule

6 January	27 March	27 May	16 June
2 August	14 September	11 October	

Table 33. Ordnance OBC Schedule

6 December	18 January	20 March	10 April
17 May	14 June	19 July	23 August
22 September	18 October	15 November	

Table 34. Quartermaster OBC Schedule

29 November	5 January	21 March	3 May
5 July	16 August	18 October	

Table 35. Signal Corps OBC Schedule

27 November	5 January	30 March	13 May
29 July	25 August	5 October	

Table 36. Transportation OBC Schedule

1 December	27 March	13 July	1 August
28 August	20 September	25 October	

APPENDIX D. EXPERIMENT DESIGN POINTS

Appendix D contains a single table that depicts the ## different design points I use in the experiment.

Design Point	BOLC Ratio	Max BOLC Size	Min BOLC Size	IA Ratio	Min Req
1	1	1	1	1	1
2	1	1	1	-1	1
3	1	1	-1	1	1
4	1	1	-1	-1	1
5	1	-1	1	1	1
6	1	-1	1	-1	1
7	1	-1	-1	1	1
8	1	-1	-1	-1	1
9	-1	1	1	1	1
10	-1	1	1	-1	1
11	-1	1	-1	1	1
12	-1	1	-1	-1	1
13	-1	-1	1	1	1
14	-1	-1	1	-1	1
15	-1	-1	-1	1	1
16	-1	-1	-1	-1	1
17	1	1	1	1	-1
18	1	1	1	-1	-1
19	1	1	-1	1	-1
20	1	1	-1	-1	-1
21	1	-1	1	1	-1
22	1	-1	1	-1	-1
23	1	-1	-1	1	-1
24	1	-1	-1	-1	-1
25	-1	1	1	1	-1
26	-1	1	1	-1	-1
27	-1	1	-1	1	-1
28	-1	1	-1	-1	-1
29	-1	-1	1	1	-1
30	-1	-1	1	-1	-1
31	-1	-1	-1	1	-1
32	-1	-1	-1	-1	-1
33	0	0	0	$-\sqrt{4}$	-1
34	0	0	0	$\sqrt{4}$	-1
35	0	0	$-\sqrt{4}$	0	-1
36	0	0	$\sqrt{4}$	0	-1
37	0	$-\sqrt{4}$	0	0	-1
38	0	$\sqrt{4}$	0	0	-1
39	$-\sqrt{4}$	0	0	0	-1

40	$\sqrt{4}$	**0**	**0**	**0**	**-1**
41	**0**	**0**	**0**	$-\sqrt{4}$	**1**
42	**0**	**0**	**0**	$\sqrt{4}$	**1**
43	**0**	**0**	$-\sqrt{4}$	**0**	**1**
44	**0**	**0**	$\sqrt{4}$	**0**	**1**
45	**0**	$-\sqrt{4}$	**0**	**0**	**1**
46	**0**	$\sqrt{4}$	**0**	**0**	**1**
47	$-\sqrt{4}$	**0**	**0**	**0**	**1**
48	$\sqrt{4}$	**0**	**0**	**0**	**1**
49	**0**	**0**	**0**	**0**	**1**
50	**0**	**0**	**0**	**0**	**-1**

APPENDIX E. MEAN ACCESSION TIME REGRESSION RESULTS

The information below depicts the results of initial regression on the mean accession time. The first column is the list of factors and their levels, if any. The second column shows the coefficients associated with the factors and levels of the regression model. The final column is the resulting the p-values for all of the input variables. Highlighted rows are those terms that are significant to the model due to their corresponding p-value less than .05.

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	353.6877	4.3849	80.6598	0.0000
BOLCRatio	2.3220	7.3972	0.3139	0.7536
BOLCDiff	0.4350	0.0139	31.3574	0.0000
MaxBOLC	-2.2404	0.0502	-44.6648	0.0000
IARatio	32.3183	12.6704	2.5507	0.0109
MinReq	-0.7527	0.4048	-1.8593	0.0632
I(BOLCRatio^2)	-6.8143	10.3748	-0.6568	0.5114
I(BOLCDiff^2)	-0.0021	0.0001	-29.5152	0.0000
I(MaxBOLC^2)	0.0093	0.0002	38.8852	0.0000
I(IARatio^2)	0.7307	24.9980	0.0292	0.9767
I(BOLCRatio^3)	3.5283	4.8865	0.7220	0.4704
I(BOLCDiff^3)	0.0000	0.0000	40.2954	0.0000
I(MaxBOLC^3)	0.0000	0.0000	-32.1701	0.0000
I(IARatio^3)	-0.9150	16.5037	-0.0554	0.9558
BOLCRatio:BOLCDiff	-0.0125	0.0077	-1.6208	0.1053
BOLCRatio:MaxBOLC	0.0198	0.0088	2.2409	0.0252
BOLCRatio:IARatio	-1.1685	1.9411	-0.6020	0.5473
BOLCRatio:MinReq	0.1062	0.3140	0.3381	0.7354
BOLCDiff:MaxBOLC	-0.0009	0.0001	-7.7591	0.0000
BOLCDiff:IARatio	0.0007	0.0116	0.0581	0.9537
BOLCDiff:MinReq	-0.0050	0.0019	-2.6377	0.0085
MaxBOLC:IARatio	-0.0395	0.0133	-2.9739	0.0030
MaxBOLC:MinReq	-0.0071	0.0022	-3.2121	0.0014
IARatio:MinReq	-0.4236	0.4712	-0.8991	0.3688

Residual standard error: 0.8009 on 1176 degrees of freedom
Multiple R-Squared: 0.9758
F-statistic: 2060 on 23 and 1176 degrees of freedom, the p-value is 0

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APPENDIX F. VARIANCE REGRESSION RESULTS

The information below depicts the results of initial regression on the variance of the grand mean. The first column is the list of factors and their levels, if any. The second column shows the coefficients associated with the factors and levels of the regression model. The final column is the resulting the p-values for all of the input variables. Highlighted rows are those terms that are significant to the model due to their corresponding p-value less than .05.

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	16.2346	5.5671	2.9162	0.0070
BOLCRatio	1.2871	4.0310	0.3193	0.7519
MaxBOLC	-0.3057	0.0604	-5.0610	0.0000
IARatio	10.3076	20.2818	0.5082	0.6154
MinReq	-1.2465	0.6370	-1.9568	0.0608
BOLCDiff	0.1107	0.0302	3.6708	0.0011
I(BOLCRatio^2)	0.1414	2.4197	0.0584	0.9538
I(MaxBOLC^2)	0.0014	0.0003	4.5574	0.0001
I(IARatio^2)	-19.0354	39.9849	-0.4761	0.6379
I(BOLCDiff^2)	-0.0007	0.0002	-2.9184	0.0070
I(MaxBOLC^3)	0.0000	0.0000	-4.0939	0.0003
I(BOLCDiff^3)	0.0000	0.0000	3.1745	0.0037
I(IARatio^3)	13.3448	26.4083	0.5053	0.6174
BOLCRatio:MaxBOLC	-0.0108	0.0136	-0.7923	0.4351
BOLCRatio:IARatio	-1.7823	3.0494	-0.5845	0.5638
BOLCRatio:MinReq	0.1469	0.4980	0.2950	0.7702
BOLCRatio:BOLCDiff	0.0125	0.0122	1.0257	0.3141
MaxBOLC:IARatio	0.0148	0.0205	0.7257	0.4742
MaxBOLC:MinReq	0.0112	0.0033	3.3668	0.0023
MaxBOLC:BOLCDiff	-0.0001	0.0002	-0.8091	0.4255
IARatio:MinReq	0.6115	0.7469	0.8186	0.4202
IARatio:BOLCDiff	-0.0255	0.0183	-1.3935	0.1748
MinReq:BOLCDiff	-0.0060	0.0030	-1.9926	0.0565

Residual standard error: 0.2587 on 27 degrees of freedom
Multiple R-Squared: 0.8771
F-statistic: 8.759 on 22 and 27 degrees of freedom, the p-value is 2.289e-007

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APPENDIX G. FORMULATION OF LOSS FUNCTION MINIMIZATION

Indicies – None

Data

bolcbrhi – high setting used for the BOLC Branch Ratio factor (.85 [scalar])

bolcbrlo – low setting used for the BOLC Branch Ratio factor (.55 [scalar])

maxbolchi – high setting used for the Max BOLC Class Size factor (250 officers)

maxbolclo – low setting used for the Max BOLC Class Size factor (150 officers)

minbolchi - high setting used for the Min BOLC Class Size factor (100 officers)

Minbolclo - low setting used for the Min BOLC Class Size factor (50 officers)

bolcdifhi – highest possible difference between max and min class size settings (200 officers) Size factor (100 officers)

bolcdiflo – lowest possible difference between max and min class size settings (50 officers)

iaratiohi – high setting used for the Immediate Active Duty Ratio factor (.6 [scalar])

Iaratiolo – low setting used for the Immediate Active Duty Ratio factor (.4 [scalar])

Variables

X_1 – BOLC Branch Ratio

X_2 - Max BOLC Class Size [Continuous] (Officers)

X_3 - Difference Between Max and Min BOLC Class Size

[Continuous] (Officers)

X_4 – Immediate Active Duty Ratio [Continuous] (Scalar)

X_5 – Min OBC Course Size Requirement [Binary]

Formulation

Min $((354.5905 - 2.2755X_2 + .4657X_3 + 32.4646X_4 - .7491X_5 - .0009X_2X_3 - .0446X_2X_4 - .0109X_2X_5 + .0096X_2^2 - .0025X_3^2 - .00001245X_2^3 + .000006855X_3^3)-82.78)^2 + 22500(e^{(17.7527 - .3126X2 + .1380X3 - .9376X5 + .0120X2X5 + .0013X22 - .0011X32 - .000001821X23 + .000002629X33)})$

Subject to

$X_1 \geq$ bolcbrlo (keep variable greater than low setting)

$X_1 \leq$ bolcbrhi (keep variable greater than high setting)

$X_2 \geq$ maxbolclo (keep variable greater than low setting)

$X_2 \leq$ maxbolchi (keep variable less than high seting)

$X_3 \geq$ bolcdiflo (keep variable greater than low setting)

$X_3 \leq$ bolcdifhi (keep variable less than high setting)

$X_4 \geq$ iaratiolo (keep variable greater than low setting)

$X_4 \leq$ iaratiohi (keep variable less than high setting)

$X_2 - X_3 \geq$ minbolclo (*)

$X_2 - X_3 \leq$ minbolchi (**)

$X_6 \leq$ minbolchi (keep variable less than high setting)

X_5 element of {0,1} (keep variable binary)

* Insure that the difference between the variable Maximum BOLC Class Size and the variable Difference Between Max and Min BOLC Class Size is not less than the low setting for Min BOLC Class Size

** Insure that the difference between the variable Maximum BOLC Class Size and the variable Difference Between Max and Min BOLC Class Size is not greater than the high setting for Min BOLC Class Size

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